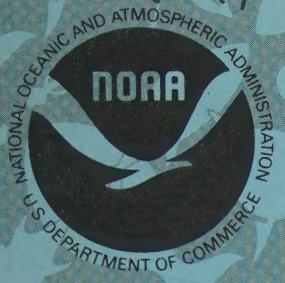
LJ-79-41



SOUTHWEST FISHERIES CENTER

NATIONAL MARINE FISHERIES SERVICE
SOUTHWEST FISHERIES CENTER
P.O. BOX 271
LA JOLLA, CA 92038

NOVEMBER 1979

REPORT OF THE STATUS OF PORPOISE STOCKS WORKSHOP (AUGUST 27-31, 1979, LA JOLLA, CALIFORNIA)

Library
NOAA, National Marine Fisheries Service
SWFC Honolulu Laboratory F/SWC2
2570 Dole Street
Honolulu, HI 96822-2396

SOUTHWEST FISHERIES CENTER
ADMINISTRATIVE REPORT No. LJ-79-41

Report of the Status of Porpoise Stocks Workshop

August 27-31, 1979

Southwest Fisheries Center
La Jolla, California

Tim Smith, Editor

November 1979

Library
NOAA, National Marine Fisheries Service
SWFC Honolulu Laboratory F/SWC2
2570 Dole Street
Honolulu, HI 96822-2396

PREFACE

The conclusions reached in this document about the status of the several porpoise stocks involved with the tuna purse seine fleet in the eastern tropical Pacific are based on the information available to the participants of the Workshop and are the best that could be achieved in the available time. As new information and analyses become available the conclusions are subject to change. However, the Workshop participants felt that the present assessments represent a substantial improvement over previous work and should form the basis of further management decisions with respects to these stocks.

TABLE OF CONTENTS

		Page
	List of Figures	vi
	List of Tables	vii
1.0	Introduction	1
1.1	Problem and Brief History of Management	2
1.2	Terms of Reference and Charge to the Workshop	3
2.0	Management Criteria	4
2.1	Interpretation of the Marine Mammal Protection Act	4
2.2	Considerations at the Level of the Ecosystem	5
2.3	Criteria at the Level of the Population	5
	2.3.1 Maximum Net Productivity Level in Steady-State Conditions	
	2.3.2 Composition of a Population	
	2.3.3 Interspecific Relationships	
3.0	Data and Methodology: Description and Assumptions	11
3.1	General Data Sources	11
3.2	Definition of Stocks and Boundaries	12
	3.2.1 Stock Definitions and Habitats	
	3.2.2 Characteristics of the Stocks	

Table of Contents (Continued)

		Page
3.3	Population Size Estimates	15
	3.3.1 Density of Schools (D_k)	
	3.3.2 Mean School Size (S_t)	
	3.3.3 Species Proportions (P_t and P_{ik})	
	3.3.4 Stock Sizes (N_{ij})	
	3.3.5 Other Species	
	3.3.6 Other Papers	
3.4	Incidental Kill	25
	3.4.1 Direct Kill, All Fleets 1959 to 1972	
	3.4.2 Direct Kill, U.S. Fleet 1973 to 1978	
	3.4.3 Direct Kill, Non-U.S. Fleet 1973 to 1978	
	3.4.4 Serious Injury	
	3.4.5 Unobserved Kill	
	3.4.6 Unobservable Mortality	
	3.4.7 Total Porpoise Kill, All Fleets 1954 to 1978	
3.5	Reproductive Rates	33
	3.5.1 Sampling Biases	
	3.5.2 General Reproductive Biology	
	3.5.3 Gross Reproductive Rates	
	3.5.4 Net Reproductive Rates	
3.6	Methodology for Estimating Pre-Exploitation Population Levels	41

Table of Contents (Continued)

		Page
4.0	Status of Porpoise Stocks	46
4.1	Parameter Values Used	47
	4.1.1 Interpretation of Ranges of Values	
	4.1.2 Differences Between the 1976 and 1979 Assessments	
4.2	Spotted Dolphin	52
	3.2.1 Coastal Spotted Stock	
	4.2.2 Offshore Spotted Stock(s)	
4.3	Spinner Dolphin	54
	4.3.1 Eastern Spinner Stock	
	4.3.2 Northern Whitebelly Spinner Stock	
	4.3.3 Southern Whitebelly Spinner Stock	
4.4	Common Dolphin	56
	4.4.1 Northern Tropical and Baja Neritic Common Stocks	
	4.4.2 Central Tropical Common Stock	
4.5	Striped Dolphin	57
	4.5.1 Central Tropical Striped Stock	
4.6	Other Stocks	58

Table of Contents (Continued)

		Page
Literature Cited		61
Figures		63
Tables		80
Appendices		114
1.	List of Participants	114
2.	Agenda	115
3.	Definition of Optimum Sustainable Population Size (OSP)	116
4.	List of Workshop Documents	117

LIST OF FIGURES

Figure 1 Distribution of the several stocks of spotted dolphin, Stenella attenuata, in the eastern Pacific Ocean.

Figure 2 Distribution of the several stocks of spinner dolphin, Stenella longirostris, in the eastern Pacific Ocean.

Figure 3 Distribution of the several stocks of common dolphin, Delphinus delphis, in the eastern Pacific Ocean.

Figure 4 Distribution of the several stocks of striped dolphin, Stenella coeruleoalba, in the eastern Pacific Ocean.

Figure 5 Ship and aircraft survey tracks used in the 1979 porpoise survey.

Figure 6 Estimated current population level as a proportion of pre-exploitation level (N_{79}/N_p) plotted against the corresponding MNPL, for 3 stocks and 3 values of R_{max}.

Figures 7 thru 16

Estimated population size ($x10^5$) over time for the several porpoise populations, using the unadjusted estimates of population size, MNP level of 72.5% of pre-exploitation abundance, and maximum net reproductive rate estimates of 0% (circle), 2% (square) and 4% (triangle). All graphs include zero abundance to illustrate the general magnitude of the reductions in population size which have occurred; inset graphs show the estimates of abundance for 1976 to 1979 on an expanded abundance scale to illustrate the recent history of the populations. The particular abundance estimates and MNP level used were selected for illustrative purposes only, and do not indicate preferred or most likely values.

Figure 7 Coastal spotted dolphin

Figure 8 Northern offshore spotted dolphin

Figure 9 Southern offshore spotted dolphin

Figure 10 Combined northern and southern offshore spotted dolphin

Figure 11 Eastern spinner dolphin

Figure 12 Northern whitebelly spinner dolphin

Figure 13 Southern whitebelly spinner dolphin

Figure 14 Northern tropical common dolphin

Figure 15 Central tropical common dolphin

Figure 16 Central tropical striped dolphin

LIST OF TABLES

Table 1 — Management, scientific, and legal actions and events concerning the incidental kill of porpoise in the eastern tropical Pacific tuna purse seine fishery.

Table 2 — List of major stocks and minor stocks of porpoise involved in the eastern tropical Pacific purse seine fishery. Area inhabited (nm^2) by the major stocks is shown.

Table 3 — Sampling intensity from the research vessels in areas near the equator to determine the magnitude of possible biases in population estimates due to possibly non-uniform density of porpoise.

Table 4 — Mean perpendicular sighting distance (P) and Beaufort number (B) for each research vessel sighting, by ship, species composition, area and sighting cue. Sample sizes in parentheses.

Table 5 — Mean school size (S_i), proportion of total sightings for the target species $\left(\frac{n_{iA}}{n_A}\right)$ from the 1979 aerial survey data, and the ratio of density estimates for each species to the overall density estimate from the tuna vessel sighting data $\left(\frac{D_{iT}}{D_T}\right)$ by species.

Table 6 — Estimates of the proportions (P_{ik}) of each of the target species in the three statistical areas, adjusted for differences in detectability.

Table 7 — Estimates of 1979 population sizes by stock for target species in thousands of animals. Estimated standard deviations for the unadjusted estimates shown in parentheses.

Table 8 — Minimal population size estimates for non-target species from the 1979 aerial survey data in thousands and estimates of relative density of schools from tuna vessel observer data. 1977-1979 mean school density per 1000 square nm.

Table 9 — Estimate numbers of porpoise killed directly by all fleets in the years 1959 to 1972, by stock, and in total. Also given are the corresponding total estimates used in 1976 (SOPS/79/1, p. 6-8).

Table 10 — Estimated numbers of porpoise killed directly by the U.S. fleet in the years 1973 to 1978, by stock, with estimated standard deviations.

List of Tables (Continued)

Table 11	Estimates of kill-per-set for the non-U.S. fleet by year, for successful and unsuccessful sets, obtained by interpolation from U.S. rates, 1973 to 1979, with estimated standard deviations (SD).
Table 12	Estimated numbers of porpoise killed directly by non-U.S. fleet, by stock and in total, from 1973 to 1978, with estimated standard deviations for the totals.
Table 13	Estimated numbers of porpoise seriously injured by the U.S. fleet, by stock, for the years 1975 to 1978. The estimated numbers seriously injured in other stocks are almost all zero or very small, and are not shown.
Table 14	Numbers seriously injured as a percent of numbers killed directly by the U.S. fleet, for spotted, spinner and common dolphin, for the years 1975 to 1978.
Table 15	Estimated total porpoise killed, by stock, from 1973 to 1978.
Table 16	Estimates of annual pregnancy rates for northern offshore spotted and eastern spinner dolphin for 1973 to 1978, by two methods.
Table 17	Estimates of gross reproductive rates (G), with 95% confidence intervals (CI) and percentages female, mature, and the annual pregnancy rate (P) under two methods, for the years indicated. Estimates are given only for stocks where sample size was greater than 100 individuals.
Table 18	Estimates of the standard deviations of the estimates of total kill of porpoise, by stock, for the years 1973 to 1978, computed as outlined in Section 3.6. These estimates are underestimates for the several reasons described there, and are used only to obtain lower bounds for the variability of the quantities given in Table 20.
Table 19	For each stock, estimates of the variances and covariances of the estimated total kill by all fleets from 1959 to 1977 (Table 15). These are used as minimal estimates of the variances and covariances of the total kill during these years (Section 3.4.7) in the calculations of the variability of the quantities given in Table 20.
Table 19a	Northern offshore spotted
Table 19b	Eastern spinner
Table 19c	Northern whitebelly spinner
Table 19d	Central tropical common

List of Tables (Continued)

Table 20 For each stock, estimated pre-exploitation stock size ($\hat{N}_p$), ratio of present stock size to this level ($\hat{N}_{79}/\hat{N}_p$), and replacement yields ($\hat{RY}$), for present abundance estimates ($\hat{N}_{79}$) by two methods, for values of maximum net reproductive rate ($\hat{R}_{max}$) of 0, 2, and 4 percent, and for levels of population size (relative to $\hat{N}_p$) at which maximum net productivity of the population is obtained (MNPL) of 65, 72.5, and 80 percent. The population size estimates are obtained either accounting for suggested adjustments to the species proportions (adjusted), or not (unadjusted). The asterisk (*) indicates that a MNP level is not defined when $\hat{R}_m = 0$. Estimates of the standard deviations of the ratio of $\hat{N}_{79}/\hat{N}_p$ and of $\hat{N}_p$ are shown in parentheses.

Table 20a Coastal Spotted

Table 20b Northern Offshore Spotted

Table 20c Southern Offshore Spotted

Table 20d Offshore Spotted Porpoise

Table 20e Eastern Spinner

Table 20f Northern Whitebelly Spinner

Table 20g Southern Whitebelly Spinner

Table 20h Baja Neritic and Northern Common

Table 20i Central Tropical Common

Table 20j Central Tropical Striped

1.0 INTRODUCTION

The first workshop on stock assessment of porpoise (interchangeably, dolphins) involved in the eastern tropical Pacific (ETP) yellowfin tuna fishery was held by the National Marine Fisheries Service (NMFS), Southwest Fisheries Center (SWFC), in July 1976 (SOPS/79/1)*. Management actions have been promulgated based on the results of that workshop, and the incidental mortality of porpoise involved in the fishery has been reduced as improvements in gear and fishing techniques have been introduced. The NMFS management procedures have consisted of gear regulations, reduction of an annual basis of the quotas on the allowable kill of each stock, and an increased number of "porpoise observers" who accompany tuna purse seine fishing vessels. Research studies recommended by the participants in the 1976 workshop on the population biology of the porpoise stocks (SOPS/79/1, Appendix 4) have been undertaken, and since 1978 the Inter-American Tropical Tuna Commission (IATTC) has conducted a research program, including placing observers on the international fleet of purse seiners in 1979.

With expiration in 1980 of the current 3-year management regime, NMFS must propose a set of regulations to govern the U.S. tuna purse seine fishery in 1981 and possibly beyond. The NMFS-SWFC, therefore, organized a workshop of experts in population dynamics, with special emphasis on large mammals, to re-assess the status of the porpoise stocks involved in the eastern tropical Pacific yellowfin tuna fishery. The workshop was held August 27-31, 1979, at the SWFC, La Jolla, California, and was chaired by Dr. Tim Smith, SWFC. Participants are listed in Appendix 1.

* Meeting documents are indicated by the prefix SOPS/79/--, and are listed in Appendix 4.

1.1 PROBLEM AND BRIEF HISTORY OF MANAGEMENT

Purse seine fishing for yellowfin tuna in the eastern tropical Pacific often involves porpoise found in association with yellowfin tuna. This association is used by tuna fishermen, who pursue and capture the porpoise-yellowfin tuna complex, and then release the porpoise from the net while retaining the yellowfin tuna. During this fishing process, incidental mortality of porpoise occurs.

Available information indicates that purse-seine fishermen used this technique as early as 1959, and that prior to that the baitboat fleet also utilized this association although without incidental mortality of porpoise. In the mid-1960's the Bureau of Commercial Fisheries, predecessor of the National Marine Fisheries Service, conducted limited research to document the situation and to collect data on the mortality and stocks involved. After the passage of the Marine Mammal Protection Act (MMPA) in 1972 substantial research efforts were mounted to assess the status of the stocks and to develop procedures for reducing the incidental mortality and serious injury of porpoise.

Since 1972 a series of management and legal actions have been taken (Table 1). The 1976 Richey decision has had the most impact on interpretation of the MMPA, with specific requirements being set down in terms of information required for granting of permits for the taking of porpoise associated with tuna fishing. The most important provisions of this decision require (Richey, 1976)

> "...reasonable estimates of (1) the existing population level of each species of porpoise affected by the proposed regulations, (2) the optimum sustainable population (OSP) of each of these species, and (3) the expected impact of those regulations on the effort, mandated by the Act, to achieve an optimum sustainable population level for each species."

This judicial requirement for information acted as a clarification of parts of the MMPA, but did not define the term "optimum sustainable population." The 1976 workshop on the status of the porpoise stocks was able to provide an interpretation of this concept (SOPS/79/1), which was subsequently used as the basis of the definition published by NMFS in the Federal Register (Appendix 3).

1.2 TERMS OF REFERENCE AND CHARGE TO THE WORKSHOP

The terms of reference were the Marine Mammal Protection Act of 1972, the Richey Decision of 1976, and the existing definition of optimum sustainable population (Appendix 3). The charge to the group was to assess the status of the porpoise stocks involved with the tuna purse seine fleet using the best available scientific information. This assessment should specifically include for each stock (population): (1) estimates of existing population size; (2) estimates of the existing population size relative to the optimum sustainable population of the stock; and (3) estimates of the impact of various levels of incidental mortality. Additionally, the workshop was charged to consider criteria upon which

management decisions pertaining to the status of the porpoise stocks could be based, in addition to or as alternatives to the specific items listed above.

2.0 MANAGEMENT CRITERIA

To respond to the MMPA (SOPS/79/47) it is necessary to determine if any particular stock, population, species, or ecosystem is being affected in any way such that the intent of the Act is violated. This presupposes that these elements may be characterized in ways which permit their evaluation in relation to the requirements of the Act. Determination of the status of stocks requires, however, a clear interpretation of the wording of the Act. The purpose of the consideration given these matters in the workshop was to: (1) review the application of existing management criteria (Appendix 3) in the light of both the management experience since 1976 and new scientific information; (2) determine if there are new feasible criteria which should be erected and; if so, (3) make as much progress as possible toward the implementation of these criteria.

2.1 INTERPRETATION OF THE MARINE MAMMAL PROTECTION ACT

The workshop participants recognize and reiterate that from the scientific point of view the Act is in places ambiguous, and more seriously, that it contains certain provisions, and there have been subsequent interpretations, which may not be operationally possible to implement now or in the forseeable future. In particular, words such as "health" are not well

defined insofar as they apply to ecosystems, populations and stocks. Given this constraint, however, the participants recognize the need to establish feasible means of implementing the Act.

2.2 CONSIDERATIONS AT THE LEVEL OF THE ECOSYSTEM

Species interactions, especially those between species being harvested and those directly affected by harvested populations, are of considerable importance in the rational management of any population. Predator-prey interactions, competition, symbiosis and other coevolutionary relationships are important in evaluating the impact of harvest or incidental take and in defining reasonable management criteria. The composition and nature of the marine ecosystem in which the porpoise stocks are involved are of particular importance in the issues faced by this workshop. The participants agree, however, that there is currently little hope of using ecosystem criteria in the assessment of these dolphin populations, mainly because a great deal more information and understanding about the eastern tropical Pacific ecosystem would be needed. Such information has not been obtainable to date because of limitations on our understanding of how to study ecosystems, because of the long time frames which would be required, and because of funding constraints. Nothing more at the ecosystem level can be done at this time than to point out the importance of the issues and to describe examples of cases where current insight may be of help.

2.3 CRITERIA AT THE LEVEL OF THE POPULATION

In view of our inability to offer operational criteria at the level of the ecosystem, considerations at the level of the population take on greater importance. The participants briefly reviewed the definition of optimum sustainable populations (OSP) as adopted by the National Marine Fisheries Service (Appendix 3). It was emphasized that the current definition of OSP does not specify a single population level as optimum, but rather defines a range of levels which includes the optimal level. The range extends from the population level which is the largest supportable by the ecosystem, to the population level that results in the maximum net productivity (MNPL). Not all of the workshop participants found the NMFS definition totally satisfactory, but in the time available it was agreed that substantial improvement in this definition was not possible. The value of MNPL for large mammals in general and for dolphins in particular was discussed, resulting in consolidation of opinion within the group that the MNPL is likely to be in the range of 65 to 80% of the equilibrium unharvested population level (carrying capacity, or largest supportable population). In the absence of better information, all levels within this range were treated as being equally likely; the midpoint (72.5%) cannot be regarded as "the most likely" value.

The workshop did not believe that it was appropriate to its task to address the questions of "safety factors" or "prudence" as was done in the 1976 workshop (SOPS/79/1, page 7).

Three aspects of the problem of determining the lower bound of the OSP, that is the level of the maximum net productivity (MNP), were identified:

(1) uncertainty as to the level of MNP in steady-state conditions;

(2) the consequences of departures of the composition of the

population by age, sex, reproductive state or other quality from steady state conditions; and

(3) the effects of inter-specific relationships between the several dolphin populations and also with the tuna populations.

2.3.1 MAXIMUM NET PRODUCTIVITY LEVEL IN STEADY-STATE CONDITIONS

The 1976 workshop (SOPS/79/1) had tentatively concluded that the MNP level was likely to be somewhere between 50 and 70% of the "initial" (unexploited) population level, and subsequent to the meeting some participants expressed the opinion that "a more definite statement must be made" and that 60% would be a "prudent approximation" (see footnote, SOPS/79/1, page 7). The participants in the present workshop recognize that there has been a shift of scientific opinion in recent years towards accepting the idea that relative net productivity in mammals, especially large, K-selected species is a non-linear function of population size (SOPS/79/15). We note that in addition to the availability of more data and re-evaluations of existing data, this shift of opinion may represent a lessening of earlier emphasis on the results of the symmetrical logistic curve and of dependence on data for smaller r-selected animals.

A summary of evidence for a number of species of large mammals showing nonlinearity in specific productivity as related to density was reviewed (SOPS/79/15). Theoretical arguments were advanced favoring nonlinear relationships which result in MNP levels significantly higher than 50% of

equilibrium abundance. These arguments involved trophic interactions, evolutionary considerations, social structure and life history strategies. There is empirical evidence of this pattern in wild populations of mammals which have been intensively studied, including some which have been subjected to experimental manipulation. Most of the evidence is for terrestrial species.

Additional evidence for MNP occuring at high population levels in large mammals, both terrestrial and marine, is given in Fowler, et al (1978) and in McCullough (in prep). Estimates of the MNPL for a whitetailed deer population in George Reserve, for a bighorn sheep population on Wild Horse Island, for a grizzly bear population in Yellowstone National Park, and for an elephant population in east Africa were given by McCullough as 56, 62, 66 and 86% of carrying capacity, respectively. These estimates were not reviewed in depth by the workshop, but do suggest an increasing trend in MNPL for animals with higher ages of sexual maturity. There is discussion of such tendencies for marine species as provided in Chapman (in press). Only a small part of the evidence for such nonlinearity involves cetaceans, and there is no direct evidence regarding the dolphin species involved in the tuna fishery. The group agrees that it is very unlikely that MNP levels of the dolphin populations involved in the fishery can be estimated directly in the near future, regardless of the level of research which might be conducted. Consequently, management decisions, if they are to continue to involve specification of MNP levels, must be made with respect to levels presumed on the basis of indirect evidence, particularly evidence from comparisons among species.

2.3.2 COMPOSITION OF A POPULATION

Assuming no environmental fluctuations, a population will not necessarily remain constant even if a number of animals equal to the net productivity as discussed in 2.3.1 is removed from it. Whether it will remain constant or change depends on the composition of the population by age, sex or reproductive state and on the composition of the portion of the stock removed.

There are too many uncertainties in present information on the age structure of dolphin populations in the eastern tropical Pacific (SOPS/79/51) to permit firm conclusions to be drawn with respect to trends in the populations. Nevertheless, provision should be made in the management criteria to avoid the possibility of a population being classified as within the optimal range when, due to its age or sex structure, it would in fact decline without further removals or with removals less than the net productivity of a steady-state population of that size. The group recommends that consideration be given to redefining OSP to account for these problems.

2.3.3 INTERSPECIFIC RELATIONSHIPS

The existence of unaccounted-for interspecific relationships may alter the level of MNP as it might be judged using single-species models and concepts. In the porpoise-tuna community such relationships may be quite complex. There is some overlap in diet and there may therefore be significant competition among dolphin species (especially in mixed schools) and between the dolphins and the tuna. Differential exploitation of the various dolphin species and of the tuna, and differences in their vital parameters and in

their responses to exploitation, would lead to changes in the carrying capacity of the environment for each of them. On the other hand, it has been suggested that there may also be mutually beneficial relationships among the dolphins, and between them and the tuna. These possibilities cannot yet be evaluated even in qualitative terms; there is no early prospect of modeling them quantitatively.

It was noted that at least some of the data for nondolphin species on which the participant's judgements of probable MNP levels were based include the effects, at least partially, of inter-specific relationships such as competition, which led to changes in the carrying capacity for a species population as that population changed over time. If the interrelations within the tuna-porpoise system were of a similar nature to these examples, then application of the general conclusions from them to the present problem would be quite appropriate. Unfortunately, not enough is known about the tuna-porpoise relationship to be able to affirm or deny such similarity. Little is known about the dynamics of the common food resources, or about other possible competitors (such as cephalopods) in the system.

The pre-exploitation population level for each stock is taken to be the best available estimate of the carrying capacity of the environment for that stock. As noted, this assumption disregards the possible interaction between porpoise stocks as well as possible effects of the substantial reduction in the populations of tuna that took place prior to the beginning of the incidental killing of porpoise. These changes in the other populations may have had significant effects on the carrying capacity of the environment for porpoise, if the carrying capacity is taken to be the level to which the porpoise populations would ultimately expand in the absence of killing of porpoise. Lacking sufficient knowledge of the interactions in the ecosystem

to account for these changes, the participants agreed that the only practicable course for the present is to use the pre-exploitation population levels to estimate the carrying capacity.

Additional justification of the present definition that OSP lies between the carrying capacity and the population level giving maximum net productivity is seen in the difference in the dynamics of populations managed under fixed quota systems when the populations are above and below the MNP level. At population levels above MNPL minor changes in numbers of animals killed will result only in changing the population level (and correspondingly the sustainable yield) to a small degree. Unless quotas are changed in response to changes in population level, at population levels below the MNP level no such equilibrium population levels exist under fixed quota management. The population below the MNP level will necessarily either decline to extinction or increase until it equilibrates at some level above the MNP level, depending on the harvest rate. In order for a population below the MNP level to recover rather than go towards extinction the harvest rate must be less than the harvest rate for MNP. While the management of porpoise has not yet been based on quotas fixed at the same level for a number of years, the stability attributes of populations above the MNP level are desirable aspects of the current definition of OSP.

3.0 DATA AND METHODOLOGY: DESCRIPTION AND ASSUMPTIONS

Described below are the data sources and methodology on which assessment of the status of the porpoise stocks is based. The analyses involved in estimating each of the key population parameters are sketched in general, but

with emphasis on the assumptions and uncertainties involved.

3.1 GENERAL DATA SOURCES

Data for stock assessment are obtained primarily through a program of placing biological observers aboard tuna purse seine vessels fishing in the eastern tropical Pacific. The observers have recorded data of six different general types (SOPS/79/46), primarily from 1973 to 1979, with lesser amounts being collected in 1971 and 1972. Some information on the number of porpoise killed in 1964, 1966 and 1968 is also available. Information on the characteristics of the fleet, and the number of sets made, and the amount of tuna caught in association with porpoise over the years is available from the IATTC.

In addition to these data, several other types of data have been collected less for specific projects. Aerial sighting data were gathered in 1974, 1977, and 1979; research vessel sighting survey data were taken in most years since 1975.

The sampling scheme for placement of observers on tuna boats has evolved somewhat over the years, with a stratified random selection of vessel trips from 1974 to the present. The porpoise sampled for biological material are a sample of the dead animals brought aboard the fishing vessels. These sampled porpoise are themselves a sample of the animals captured in the purse seine, which are, in cases where an entire herd is not entrapped, a sample of the animals in the original herd. The representativeness of the animals examined is subject to many possible types of bias, as discussed below.

3.2 DEFINITION OF STOCKS AND BOUNDARIES

Twelve species and 22 separate stocks of dolphins are now recognized as involved in the tuna fishery in the ETP. The major stocks, those most frequently involved in the yellowfin tuna purse seine fishery, are listed in Table 2 along with the estimated area of their respective habitats. Also listed are 9 minor species that are not usually associated with tuna, and therefore not set on in tuna purse seine fishing except accidentally.

3.2.1 STOCK DEFINITIONS AND HABITATS

A species may be differentiated into one or more stocks. A stock is defined as a population unit having limited genetic exchange with adjacent units of the same species. It is the basic population unit of concern in the management of exploited species. Stocks are differentiated on the basis of (1) a hiatus in spatial distribution, or of (2) differences in morphological characters not subject to change with population density.

The four major species, spotted dolphin (Stenella attenuata), spinner dolphin (S. longirostris), striped dolphin (S. coeruleoalba), and common dolphin (Delphinus delphis) have been partitioned into 14 stocks within the ETP. The boundaries to these stocks are shown in Figures 1 to 4. These boundaries were developed from analysis of morphological data and from examinations of sighting data from tuna purse seine and research vessels from 1976 to the present. Consideration was given to the oceanography of the region and biological information in developing the stock boundaries within each species (SOPS/79/14, SOPS/79/36). Some sightings are, and will be,

reported from areas outside these stock boundaries. Such sightings are considered to be rare events occurring beyond the area of the central ranges and the largely coincident surface fishery. In the central Pacific, many such sightings are associated with islands, and ecological relationships different from those in the ETP may be involved. The boundaries shown are probably maximal with respect to the habitat area of each stock, because they were developed from consideration of the combined distributions over all seasons and years. Possible seasonal and annual movements, which could result in the population inhabiting only part of the entire area at any one time were not considered by the workshop participants. The potential for biases in the population estimates due to seasonal movements and between year variability is discussed in Section 3.3.

3.2.2 CHARACTERISTICS OF THE STOCKS

1. Spotted Dolphin (Figure 1)

Coastal:	Morphologically modally distinct; within 50 miles of coast
Northern Offshore:	Mainly in tropical waters in ETP
Southern Offshore:	Some morphological differences may be due to effects of sampling bias, effects of differential exploitation, or small sample sizes. Difficult to separate from northern stock by external appearance alone. Because of the uncertain status of northern and southern stocks they are assessed both combined and separated.

2. Spinner Dolphin (Figure 2)

Eastern:	Morphologically modally distinct; mainly in tropical waters influenced by Calif-

fornia and Costa Rican coastal currents.

Costa Rican: Localized, distinct nearshore form off southern Central America (Perrin, 1975).

Northern Whitebelly: Overlaps with eastern stock and extends westward.

Southern Whitebelly: Can be separated from northern whitebelly form by external appearance as well as other characteristics.

3. Common Dolphin (Figure 3)*

Northern Temperate: Not involved in the tropical fishery.

Baja Neritic: Nearshore and local off Baja California on both coasts.

Northern Tropical: Distinct distributional lobe off southern Mexico and in vicinity of Revillagigedo Islands.

Central Tropical: Distinct lobe in tropical waters of North Equatorial and North Equatorial Counter Currents. A possible subdivision into eastern and western central stocks, as suggested by an intermediate region of infrequent sightings, was considered and provisionally rejected by the workshop on the basis of insufficient evidence of separation, pending availability of morphological data.

Southern Tropical: Distinct lobe in equatorial and southern subtropic waters.

Southern Temperate: Not involved in the purse seine fishery.

4. Striped Dolphin (Figure 4)

Northern Temperate: Not involved in the tropical fishery.

Northern Tropical: Distinct lobe off Mexico and in vicinity of Revillagigedo Islands.

Central Tropical: Distinct lobe in tropical waters of N. Equatorial and N.

* Evidence for the distinctiveness of Delphinus stocks in the eastern Pacific is given in Evans (1975).

	Equatorial Counter Currents. A possible subdivision into eastern and western central stocks, as suggested by an intermediate region of infrequent sightings was considered and provisionally rejected by the workshop on the basis of insufficient evidence.
Southern Tropical:	Distinct lobe in equatorial and southern subtropical waters.
Southern Temperate:	Not involved in the tropical fishery.

3.3 POPULATION SIZE ESTIMATES

Stock size (Nij) is estimated for the jth stock of the ith species as the sum over the 3 subareas (denoted by k; the inside area (Figure 5), and outside that area north and south of the equator) of the product of: (1) the density of dolphin schools (D_k); (2) the proportion (P_t) of schools containing spotted, spinner, common, striped, or Fraser's dolphin (target species); (3) the proportions (P_{ik}) of the ith species of the target group within the kth subarea; (4) the mean school size of the target species (S_t); (5) the area of the kth statistical area (A_k); and (6) the ratio of the area occupied by the jth stock of the ith species (A_{ijk}) to the area occupied by all stocks of the ith species in the kth subarea (A_{ik}). Mathematically this is shown as (SOPS/79/29)

$$\hat{N}_{ij} = P_t S_t \sum_{k=1}^{3} D_k P_{ik} A_k \frac{A_{ijk}}{A_{ik}}$$

Estimates of the several components for this equation are described below.

3.3.1 DENSITY OF SCHOOLS (D_k)

Line transect theory was used to estimate the density of schools for the inshore area, surveyed from an airplane, shown in Figure 5. It was noted that this method accounts for differences in sighting efficiency in relation to weather conditions, observer skill, etc. Several models for the decreasing probability of detecting schools with distance from the trackline were fitted, including Fourier series, exponential polynomial, and negative exponential. Criteria for selecting a model to apply to these data were developed in an earlier series of workshops (SOPS/79/29). The criteria used are (1) robustness of the model to varying detection probability curves; (2) robustness of the model to pooling data for varying sighting conditions; (3) the shape of the model detection probability curve being flat near the trackline; and (4) the efficiency of the estimation techniques as measured by the coefficient of variation of the estimated density of schools. The Fourier series was selected because it best fit the model selection criteria (SOPS/79/29).

All estimates were made for schools of 15 or more animals because it is believed that the probability of detecting smaller schools on the track line is not unity, thus violating an assumption of line transect theory (SOPS/79/29). The effect of this was that one target school was omitted from the analysis.

Data from two research ships were used to estimate density in two offshore areas, utilizing observations made in a "calibration area" within the inshore aircraft area. It was assumed that the densities of these two offshore areas are equal. These data were not suitable for line transect analysis, however, because of possible movement of schools away from the

vessel (Au and Perryman, in prep.), and of an inordinate number of schools sighted at an estimated perpendicular distance of 0. Instead of using line transect techniques, estimates for density of schools in the outside areas were made by multiplying the density estimated using the airplane data in the calibration area by the ratio of schools sighted per mile searched in the outside areas to that in the calibration area for each vessel. The final density estimate for the outside areas was the average over the two vessels, weighted by miles searched.

This method of estimating population density, by extrapolating the observed density along the track lines by the ratio of the size of the area covered to the size of the statistical area, depends upon the assumption of a uniform density over each statistical area. If the density is not uniform, bias could be introduced in the estimate of the population; the extent of these errors would depend upon the location of the track lines in relation to the changes in density within the statistical area. If the length of track line within each region having a different characteristic density is in proportion to the size of the region, no error will be introduced. If, however, the track lines are not proportional to the size of the regions, substantial errors could be introduced.

No good data were available on the distribution of density within the statistical areas, but it was suggested that a region of seasonally low density may exist in a band about 3^{o} on each side of the equator from about 95^{o}W westward. To explore the possible magnitude of such biases, the numbers of days searched in 1979, the approximate area (in 1-degree squares), and searching intensity in the regions covered were obtained, as shown in Table 3.

In this case, the searching intensity in the equatorial region was greater than in remaining portions of the statistical areas. Therefore, if

the population density in the equatorial region is lower than that in the rest of the outside statistical areas, the assumption of a uniform density would lead to an underestimate of population.

It was agreed that if an attempt were to be made to remove biases of this kind, it would be necessary to identify regions of low and high density within the statistical areas, and to develop separate estimates for each of these. While such regions could probably be identified, it was not possible to do so at this meeting; the matter should be examined further.

Two additional points about the use of research ship data were considered. The question was raised as to whether the sighting conditions differed among statistical areas, as this could bias the estimates. Data were presented to show that conditions as measured by mean Beaufort number were similar in all areas (Table 4), and the participants agreed not to pursue this point further.

It was thought that the proportion of sightings associated with birds was likely to be greater in the inshore areas than the offshore areas, and that this might bias the estimates of the density of schools as measured by number of sightings per mile searched. This is due to the greater perpendicular distance at which bird associated schools are generally seen. Data were presented to show that this may be the case as shown in Table 4. It was decided that this effect should be eliminated by using only the ship data out to a perpendicular distance of 1.1 nm.

3.3.2 MEAN SCHOOL SIZE(S_t)

There were several sources for school size, all of which had problems. It was felt that the agreement between observer counts and counts from photographs of the same school offered some justification for using the

estimates from the aerial survey.

The tuna vessel observer estimates were not used because tuna vessels may selectively search for larger schools which are more likely to be associated with tuna. Similarly, research vessel estimates were not used because the recorded estimates were the result of an "informal" averaging process of one or more observers and there was no supporting evidence for the accuracy of these estimates as there was for the aerial survey estimates.

The probability of sighting a school is apparently related to school size, especially at great distances. The average school size was calculated using weights of 1/ln(s), where s is the estimated school size, in an attempt to remove this bias. The corrected school size for schools greater than 14 animals obtained using this procedure with the aerial survey data was 201 animals.

It was suggested that the species composition in the aerial survey data may not represent the true composition due to species specific identification problems. If this is true, the mean school size as calculated from the 1979 aerial survey data (corrected for bias introduced by the greater probability of seeing larger schools) would need to be adjusted for species distributions of the sightings.

It was proposed to utilize the frequency of sightings by species derived from tuna vessels to correct for those of the aerial survey, obtaining an adjusted estimate, S* as

$$S^* = \frac{S_T}{S_A} S.$$

S is the mean school size from the 1979 aerial survey, as calculated in SOPS/79/29 (S=201.22), S_T and S_A are weighted school sizes calculated using

the distributions of sightings by species from the 1979 tuna vessel and aerial survey data, respectively. Formulae for S_T and S_A are:

$$S_T = \sum_i \frac{D_{it}}{D_t} S_i$$

$$S_A = \sum_i \frac{n_{iA}}{n_A} S_i$$

where D_T = the average density of schools estimated using the 1977-1979 tunaboat data (SOPS/79/25);

D_{iT} = the average density of schools of species i (i=spotted, spinner, common, striped, and Fraser's) estimated using 1977-1979 tunaboat data;

n_A = the number of schools seen by the 1979 aerial survey;

n_{iA} = the number of schools of species i seen in the 1979 aerial survey;

S_i = the mean size of schools composed solely of species i as calculated from the 1979 aerial survey data.

The data for making this adjustment are given in Table 5. From those data the correction factor is S_T/S_A=1.15, and the adjusted mean school size (S*) is equal to 230.69 animals.

Two arguments against this adjustment were given. First, there was a doubt that the tuna vessel data did, in fact, reflect the true distribution of schools by species because the tuna vessels are searching for species likely to be associated with yellowfin tuna. Second, it was suggested that the adjustment was not needed because the probability of sighting a school from an airplane is only affected by species as it relates to the higher likelihood of seeing larger schools. Since adjustments for school size were already made,

there was no need to adjust for species proportions. No agreement could be reached upon whether or not the adjustment should be used.

3.3.3 SPECIES PROPORTIONS (P_t and P_{ik})

Apportioning the density of dolphin schools to species involves two separate steps. The first is to estimate the proportion of all observed schools that are target schools, P_t. This proportion is determined from the pooled data of the airplane and research ships, and is used in estimating density of schools from both aerial and research vessel data.

The second step is to estimate for each target school the proportion of individuals (P_{ik}) of the ith species in the kth area. There was a lack of confidence in the representativeness of species identification from the aircraft, and a lack of data from research vessels in certain statistical areas. Therefore, pooled research and tuna vessel data were used to estimate the P_{ik}'s. The P_{ik}'s are the ratio of N_{ik}, the total number of individuals in species i in area k, and N_k the total number of individuals in area k. An estimate of this porportion can be made from the ratio of the numbers of individuals observed in species i (n_{ik}) to the number of individuals of all species observed in the kth area (n_k), or

$$\hat{P}_{ik} = \frac{n_{ik}}{n_k}$$

However, this proportion will not be an unbiased estimate of P_{ik} unless the probability of observing one individual is the same for all species. This probability will be a function of the average school size of the species, the

behavior and habits of the species as it affects its detectability, and in the case of tuna boat data, the motivation for searching and reporting the observation of a particular species as it affects the detectability. The estimates of these proportions given in SOPS/79/29 are from a modification of this formula, correcting for differences in average school size among species.

An alternative estimator of P_{ik} was suggested to account for the various detectability differences noted above. That estimator is a ratio of estimates of the density of individuals of the ith species to the overall density of individuals from tuna and research vessel observer data. This can be expressed (for the ith species and the kth area) as

$$\hat{P}'_{ik} = \frac{n_{ik}\hat{f}_i(0)S_{ik}}{\sum_{\ell} n_{\ell k}\hat{f}_\ell(0)S_{\ell k}}$$

where n_{ik} is as defined above, $\hat{f}_i(0)$ is as defined in SOPS/79/29, and S_{ik} is the mean of the school size estimate by tuna and research vessel observers. The estimates of $\hat{f}_i(0)$ are obtained for each species for all areas combined, thus assuming that the detection function for each species is the same over all areas. These estimates are obtained using a Fourier series estimator for common and striped dolphin, and an exponential power series estimator for spinner and spotted dolphin. The estimates of the proportions pooled over the years 1977-1979 are shown in Table 6. This procedure has not been applied to Fraser's dolphin and the "other" category due to the sparse nature of the data.

Use of these estimates of species proportions was not completely agreed to. Although these adjustments reduce the bias from detectability, they are also affected by any problems in estimating $\hat{f}_i(0)$. These problems include

both movement of the porpoise relative to the ships, and measurement error.

3.3.4 STOCK SIZES (N_{ij})

The above parameter estimates can be combined in the formula for estimating N_{ij} given at the beginning of this section. The workshop agreed to handle the alternative methods for estimating species proportions P_{ik} and mean school size S_t by considering two sets of estimates: "unadjusted" where neither adjustment described in Section 3.3.2 and 3.3.3 are used, and "adjusted" where both adjustments are made. The resulting estimates are shown in Table 7. Variancès for the unadjusted estimates are given as described in SOPS/79/29, but have not been computed for the adjusted estimates due to the complexity of the adjustments used.

3.3.5 OTHER SPECIES

Population estimates are also made for the nontarget species within the airplane survey area. These estimates are made utilizing only the sightings of schools greater than 14 individuals because the sightings of small schools are not suitable for line transect estimation techniques. It is not felt that the small schools directly on the trackline could be detected with certainty. Additionally, the distribution of the perpendicular sighting distances for small schools suggests that detection declines very rapidly with distance from the trackline. These distributions generally did not provide a good fit to the various line transect models. Because of this data selection and because

estimates are made for only one statistical area, the resulting population estimates shown in Table 8 are minimal values.

Some additional information is available from the tuna vessel observer sighting data in the form of estimates of relative density of schools (SOPS/79/25). These estimates are shown also in Table 8. It appears that the abundance of these species relative to each other is markedly different as estimated from these two sets of data. Although tuna vessels do not differentially search for these species, they may occur differentially with target schools, or in the case of pilot whales, they may be attracted to tuna vessels fishing in an area.

3.3.6 OTHER PAPERS

A paper relating to the possibility of using Grampus griseus as an index species in aerial surveys was briefly presented and discussed (SOPS/79/23). It was noted by the workshop that due to this species' small school size and habit of deep diving, it may not be true that all schools on the track line are seen.

A further document (SOPS/79/25) giving preliminary estimates of the relative density of schools based on sighting from tuna boats was also briefly presented and discussed. It was noted that once some inconsistencies had been minimized with respect to differences between areas, the technique may provide a useful measure of relative abundance for certain unexploited species. Considerable problems with the data for spinner and spotted dolphins were noted by the workshop. It was also suggested that trends in the indices could indicate changes in the density of the exploited species relative to the

unexploited species. The results of this paper were used in the above developed "adjusted" population size estimates, and in relative density of non-target species.

3.4 INCIDENTAL KILL

The basic approach of estimating the numbers of porpoise killed by the fishery for each year from 1959 to 1978 is similar to that developed in the 1976 workshop (SOPS/79/1, Appendix 6). The estimation is handled differently for the years 1973 to 1978, where we have sufficient data, than in the years 1959 to 1972 where considerably fewer data are available. It is also useful to divide the estimation into these two time periods because of the apparent changes in kill rates on U.S. vessels following the passage of the Marine Mammal Protection Act of 1972.

The estimation of the number of porpoise killed is also handled differently for U.S. and non-U.S. registered vessels during the 1973 to 1978 period. This corresponds to assumed different changes in kill rates over time for the two types of vessels in that non-U.S. vessels have not been subject to the MMPA.

As noted in SOPS/79/1, a number of porpoise, while not killed outright, sustain serious injuries during the process of the purse seining operation. Data on the numbers of porpoise seriously injured are available for the U.S. fleet for the years 1975 to 1978.

A basic piece of data in all of the estimates of number killed or injured is the number of purse seine sets on porpoise each year. These are obtained from the IATTC, and assume the IATTC logbooks are representative and

that the locations are accurate. Adjustments are made on these data for non-reported sets by prorating from the yellowfin tuna catch (SOPS/79/1).

The differences in the available data in these different time periods require that various components of the total incidental kill be estimated separately, using different methods in different periods, and then subsequently combined.

3.4.1 DIRECT KILL, ALL FLEETS 1959 to 1972

Estimates of the direct kill of porpoise in this period by all fleets are obtained using different techniques and, in part, different data than were used in the 1976 workshop. The overall procedure (SOPS/79/27) is still based on stratified kill-per-set statistics and numbers of sets on porpoise, but fewer strata were used and the use of backdown by the fleet was accounted for with a piecewise linear interpolation between years where data are available.

Estimates of the number of sets on porpoise by all fleets are given in SOPS/79/1 for the years 1959 to 1970, stratified by vessel capacity and yellowfin catch. Estimates of the number of porpoise sets for 1971 and 1972 are obtained from the IATTC, stratified for the U.S. fleet, but not stratified for the non-U.S. fleet. Estimates of the stratified numbers of sets for the non-U.S. fleet are made by prorating according to the U.S. fleet information.

Information on kill rates and on the use of the backdown procedure for cruises aboard U.S. vessels in 1964, 1966, 1968, 1971 and 1972 are described in SOPS/79/27. Due to the limited amount of information available, the data are stratified to 2 vessel capacity catagories and 2 yellowfin tuna catch categories, for a total of 4 strata in all. It is assumed that in these years

the kill rates were the same for both U.S. and non-U.S. vessels.

Estimates of the direct kill for all stocks by year are obtained as the sum over the four strata of the product of mean kill-per-set rates and number of sets. Estimates of the direct kill by stock are obtained by multiplying the estimates of all stocks by the appropriate proportion for that stock.

The estimates of the proportions of the kill of each stock are derived using the estimates of the direct U.S. kill by stock for 1971 and 1972, based on the stratified kill-per-set procedure described in SOPS/79/7. The ratio of the kill of the individual stocks to the total kill for 1971-1972 is used to estimate the kill by stock from the total kill estimates from 1959 to 1972 as described in SOPS/79/27. The proportions for offshore spotted (0.700) and common dolphin (0.038) are assumed to apply to the northern and central stocks respectively, and apply to the kill for all years. The spinner proportion (0.262) is assumed to apply to the eastern spinner stock from 1959 to 1968. Starting in 1969 the fishing effort expanded to areas inhabited by the northern whitebelly spinner stock (SOPS/79/1). Thus, for the years 1969 to 1972 the total kill is allocated to eastern (0.233) and whitebelly spinner (0.029).

Because of the techniques used in obtaining these estimates of numbers killed, the estimates for different years are highly correlated. As these estimates are used in combination in estimating pre-exploitation abundances (Section 3.6), the nature of the variances and covariances are important. This is discussed in SOPS/79/27, and estimates of these quantities are given.

The estimates of the direct kill of porpoise by all fleets by stock are given in Table 9. While these estimates are based on small data sets, they represent an improvement over those given in SOPS/79/1, and the group agrees that these are the best available. If the assumption that the U.S. and non-

U.S. fleets have the same kill rates is incorrect, the effect is minimal because of the small proportion of the sets which were made by non-U.S. vessels.

3.4.2 DIRECT KILL, U.S. FLEET 1973 to 1978

The estimation procedures used in SOPS/79/1 and SOPS/79/7 are used for the annual porpoise mortality estimates for the U.S. fleet for the period 1973-1978. For each year, the porpoise sets are stratified into 32 strata, according to amount of tuna caught (greater and less than 1/4 ton), fishing location, and vessel capacity. For each stratum, mean kill-per-set is computed for each stock. The mean kill-per-set is then multiplied by the total number of porpoise sets made in that stratum by the U.S. fleet to yield the estimated porpoise mortality within that stratum. Total annual porpoise mortality is the sum of the estimates over all strata.

The participants discussed the statistical properties of various kill rates, namely kill-per-set, kill-per-day, kill-per-ton, and kill-per-trip. It was suggested that the kill using these four different kill rates should be compared. It was noted that the kill-per-set method provides estimates with lowest variances.

The estimated numbers killed directly by the U.S. fleet are shown in Table 10, with estimated standard deviations.

3.4.3 DIRECT KILL, NON-U.S. FLEET 1973 to 1978

Although it is reasonable to estimate the direct kill for all fleets using the same kill rates for the years prior to the passage of the Marine Mammal Protection Act in 1972, it is likely that the U.S. kill rates began to decline following that year at a rate greater than those of the non-U.S. fleet. Little data on non-U.S. kill rates are available, however, and the differences in the respective rates are primarily conjectural.

The only direct data on non-U.S. kill rates available are from the IATTC for part of 1979 (IATTC, 1979). To date, in 1979 the kill rates between U.S. and non-U.S. vessels are not statistically different, and in fact the non-U.S. mean kill-per-set is slightly lower than that for the U.S. fleet. Based on this limited information, the two kill rates appear to be similar by 1979. It was noted, however, that the IATTC sample did not include any small non-U.S. vessels, whose kill rate may be higher than the sampled mean. Examination of the number of sets made by such vessels suggests, however, that the effect of this on the estimates of kill would likely be small.

The best estimate of the 1973 to 1978 kill-per-set rates for non-U.S. vessels are as shown in Table 11, stratified to successful and unsuccessful sets. These estimates are obtained by assumming that the 1975 non-U.S. kill rate was the same as the 1973 U.S. kill rate, and that the kill rates for the intervening years are intermediate in value. This assumption is based on the increasing pressure by the U.S. on non-U.S. vessels for compliance in the MMPA. Thus, the non-U.S. rates are obtained by linear interpolation between three points: the observed 1971-72 mean, the above estimated 1975 non-U.S. kill rate, and the observed 1979 U.S. kill rate. The standard deviations of these estimated values are obtained accounting for the interpolation formulas, similar to the methods described in SOPS/79/27.

There are significant differences between the proportion of sets by U.S.

and non-U.S. vessels inside and outside the CYRA, and between the proportion of successful (> .25 ton) and unsuccessful (< .25 ton) sets. A higher proportion of the U.S. sets was made outside the CYRA, while a higher proportion of the non-U.S. sets was unsuccessful. However, absence of observations on kill rates for vessels fishing outside the CYRA prior to 1974 precludes stratifying to account for this area effect.

Using these estimates for the kill-per-set rates and the numbers of porpoise sets by non-U.S. vessels in this period, estimates of the direct non-U.S. kill for all stocks are shown in Table 12.

These estimates of non-U.S. direct incidental mortality for all stocks are prorated to stocks according to the direct U.S. kill by stocks. To account for the above noted area differences, however, the total non-U.S. kills in Table 12 are first allocated to inside and outside the CYRA according to the proportion of non-U.S. sets made in each area. These total non-U.S. kills by area are then prorated to stock according to the U.S. kill by stocks in each area, and the resulting non-U.S. estimates by stock by area are summed over the two areas.

3.4.4 SERIOUS INJURY

In addition to the direct kill, the observers since 1975 have counted animals that were "bleeding, had obviously broken bones, or were passed through the power block." Those animals were considered to have been "seriously injured" and some unknown fraction can be considered to have died following release. For the period 1975-78 the total numbers of animals that were seriously injured are estimated by the same method as used for the direct

total U.S. porpoise mortality in those years. These estimates are shown in Table 13.

For the years 1959 to 1974 the soundest method of estimating the number of seriously injured porpoise is to use the pooled ratio of numbers seriously injured to numbers killed for major species (Table 14). Because spotted and spinner dolphin ratios are very similar, a single value is used for both species; a separate value is used for common dolphin. The total number of dolphin seriously injured is obtained as 5.5 and 1.7 % of the estimated direct kill for spotted or spinner and for common dolphin respectively. For the non-U.S. fleet in 1975 to 1978 the numbers of seriously injured are estimated as the actual observed fraction (Table 13) for the U.S. fleet for that year.

As a conservative procedure the best estimate of the total kill of porpoise is the sum of the estimated number directly killed and the estimated number seriously injured (Table 15).

3.4.5 UNOBSERVED KILL

As less than 50% of all porpoise sets in the U.S. fleet are observed, the question of a difference in the performance of observed and unobserved sets arises. Because all vessels are similarly equipped, the major source of observed variation in performance in recent years has been in compliance or non-compliance with NMFS regulations on porpoise rescue techniques and procedures. An analysis of the effectiveness of those regulations and an algorithm to measure the effect is given in SOPS/79/10. The worst case situation in which all unobserved vessels are assumed to fail to comply with any of the significant regulations pertaining to porpoise rescue is given in

SOPS/79/28. In the worst case assumption the numbers of porpoise killed by U.S. vessels in 1977 and 1978 would be approximately double the estimated numbers killed. Although the percentage change in kill is large in this worst case example, the absolute numbers are small relative to the kill in the past and indeed, in the worst case, the kill would still be less than the current quota level.

The workshop participants recognize this as a worst case analysis and feel that it is impossible to determine where in the range between the estimated kill and the worst case kill the true value (assuming a difference between observed and unobserved vessels) would be. Thus, the possibility that the kill is higher than estimated is to be noted but is not included in the present analysis. It was also observed that mortality rates have decreased far more than is attributable only to the modifications in gear and techniques. A major share of this decrease may be due to the increased motivation on the part of the fishermen to rescue all porpoise possible. There is no information on the possible difference between vessels with and without an observer in regard to this motivation factor.

3.4.6 UNOBSERVABLE MORTALITY

Potentially, porpoise may die due to the stress of chase and capture (SOPS/79/22, SOPS/79/24). The large numbers of porpoise involved in the tuna fishery (SOPS/79/19) means that a considerable number of porpoise might be killed, even if capture stress affects only a small percentage of the animals chased or captured. For instance, 6.5 million porpoise were estimated to have been captured in 1977, compared to a total population size for all populations

of 6.4 million in 1979 (Table 7). Since no data are available on the levels of capture stress in porpoise, (SOPS/79/22), the group agrees that while additional mortality due to stress is a possibility, this factor cannot be included in our assessments until data are available. In addition to stress, unobservable mortality due to injuries not recorded as serious and other events such as interruption of calf nurture could occur.

3.4.7 TOTAL PORPOISE KILL, ALL FLEETS 1959 to 1978

The several components of the estimation of the kill described above are combined to give estimates of total porpoise mortality by stock as shown in Table 15. Estimates of the total porpoise mortality are obtained assuming, as a conservative measure, that all of the seriously injured animals in fact die due to their injuries. Thus, for 1959 to 1972 the total kill estimate is obtained by increasing the estimates of direct kill by all fleets (Table 9) by the proportions seriously injured for each species (Table 14). For the years 1973 and 1974 the total kill estimate is obtained as the sum of the direct U.S. (Table 10) and non-U.S. (Table 12) kills, increased by the proportions seriously injured (Table 14). For 1975 to 1978 the total kill is estimated as the sum of (1) the direct porpoise mortality by the U.S. fleet (Table 10), (2) the number of porpoise seriously injured by the U.S. fleet (Table 13), and (3) the direct porpoise mortality by the non-U.S. fleet (Table 12) increased by the proportions seriously injured for those years (Table 14). Estimates of the variances of the estimates for 1959 to 1972 can be obtained following the methods given in SOPS/79/27. Variances for the estimates for 1973 to 1978 have not been calculated due to the complexity of the proceedures. Note that

for these years the estimates are not independent; as for the 1959 to 1972 direct kill estimates, this non-independence should be accounted for when these estimates are combined in estimating pre-exploitation population sizes.

3.5 REPRODUCTIVE RATES

The reproductive rates of the dolphin stocks exploited by the yellowfin tuna purse seine fishery can be treated most simply by considering the difference between the rate at which new individuals are added to and removed from the population due to natural mortality each year. This difference is termed the net reproductive rate. Such descriptions, however, do not account for all aspects of changing age structures and interaction between the fishery related incidental mortality rate and the natural mortality rate.

The basic method of estimating the rate at which new individuals are added to the population (gross annual reproductive rate) is to calculate the product of the proportion of the population which is female, the proportion of the females which are sexually mature, and the proportion of the sexually mature females which are pregnant on an annual basis. Estimates of the gross annual reproductive rate (GARR) for the several species and stocks are given in SOPS/79/33 and SOPS/79/43.

Natural mortality rates are difficult to estimate for dolphin stocks. In the absence of direct estimates, however, it is reasonable to assume that in the early stages of exploitation of a large marine mammal population the natural mortality rate is equal to the gross annual reproductive rate. This is based on the concept that aside from environmental fluctuations such populations should be in equilibrium before exploitation. The natural

mortality rate can then be estimated as the gross annual reproductive rate for an unexploited population. Because of the low level of exploitation of the southern whitebelly spinner and the tentative southern offshore spotted dolphin stocks, estimates of their GAR rates can be used as estimates of natural mortality rates for the unexploited stocks.

3.5.1 SAMPLING BIASES

Observations pertaining to reproductive rates were made on animals which were a sample of the incidental kill (Section 3.1). Inferences about the reproductive rates of the population depend on the representativeness of at least 4 sampling processes:

(1) the dolphins associated with tuna are a subset of the total population;

(2) the dolphins encircled in the net are a subset of those associated with the tuna;

(3) the dolphins in the kill are a subset of those in the net;

(4) the dolphins selected by the observers are a subset of those killed.

Two possible forms of bias in the sampling processes have been detected. Analysis of time sequences of size frequency distribution for spinner porpoise indicates seasonality of reproduction (SOPS/79/26). The resulting seasonal bias of estimated parameters, however, is negligible for most stocks, because the gestation period is nearly a year and because the seasonal peaks of reproduction are somewhat diffuse. This is not true of southern offshore spotted dolphin, however, where a more substantial correction is involved.

A second possible bias for the spotted dolphin data is the relationship of the color-phase distribution to the numbers of dolphin killed in a particular set (SOPS/79/31). As the number of dolphins killed in a set declines, the fraction of the sample with neonate color-pattern increases. This suggests that the very young animals are more susceptible to being killed in the fishing operation when small numbers of animals are killed. A similar, though less marked, relationship is seen for lactating females, indicating perhaps a tendency for lactating females to remain with their young. Correction for these biases is made for the spotted dolphin by excluding from the analyses data on animals from sets where less than 40 individuals were killed.

3.5.2 GENERAL REPRODUCTIVE BIOLOGY

Data and analyses of reproductive biology and population structure of the various stocks are available in SOPS/79/4, 5, 6, 30, 33, 42, and 43. Some general constraints affecting the potential maximum net reproductive rate were discussed. Both species of Stenella have a long reproductive cycle. The gestation period is a little less than one year. The obligatory nursing period is probably about a year, but young remain associated with their mother after beginning to eat solid food, continuing to nurse intermittently for another year or even two. As lactation suppresses ovulation, this extended nursing period implies a calving interval of 2-4 years. Multiple pregnancies are rare; only one set of twin fetuses has been encountered in several thousand dissections of adult females of both species. The age at first reproduction is probably between 5 and 8 years, depending on the species and

stock. The proportion of pregnant females decreases with age, and a small fraction (< 1%) become non-reproductive. Taken together these factors imply that the life table of porpoise cannot be modified extensively at lower population densities ahd hence that maximum reproductive rates are likely rather low.

The adults can be long-lived. Kasuya reports that individuals of the Japanese population of spotted dolphins have been determined to be as old as 50 years. Known causes of natural mortality are parasitism (SOPS/79/16) and predation by sharks and other cetaceans. Predation on animals released from a tuna set is often observed, but is not known whether dolphins which have not been involved with a net set are as vulnerable to predation.

3.5.3 GROSS REPRODUCTIVE RATES

The length of the gestation period is calculated from a time sequence of measurements of fetal size distributions and mean size at birth using a model of fetal growth rates for odontocetes. One estimate of the annual pregnancy rate (method 1) is the fraction of the sexually mature females that were pregnant divided by the estimate of the gestation period. A second calculation (method 2) utilizes estimates of the gestation period, estimates of the lactation period, assuming that in the samples a suckling calf existed for each lactating female (age of weaning is the age at which the cumulative frequency of calves in a sample equals the number of lactating females), and estimates of the growth rates of nursing calves. The ratio of pregnant to resting females multiplied by the estimate of gestation period yields an estimate of the length of the resting period. The sum of these estimates of

gestation period, nursing period, and resting period gives the length of the calving cycle, the reciprocal of which is an estimate of the annual pregnancy rate. Method 2 is preferred over method 1 in that it does not depend on the relative frequency of nursing females in the kill, as it seems that females with calves are differentially vulnerable to capture and might be overrepresented in the kill. Method 2, however, does depend on all the other assumptions in method 1 and additionally is subject to sampling variability in the relative numbers of calves and nursing females, in the length of weaning calves, and in the presumed relationship between length and size in nursing calves.

The estimates of annual pregnancy rates under the two methods for northern offshore spotted and for eastern spinner dolphin are shown in Table 16. There is an apparent decreasing trend in time for the pregnancy rate estimates from method 1 for the spotted porpoise, but this is not clearly seen in the preferred estimates from method 2. There is no suggestion of trends in time for the eastern spinner estimates.

If this apparent decrease in estimated pregnancy rate and the attendent increase in length of lactation (SOPS/79/33) for the northern offshore spotted dolphin is real, it may be attributable to the large decline in the level of incidental kill over this time period. The known relatively high vulnerability of calves (Section 3.5.1) implies an artifically shortened lactation period. This would also occur if the physical and social disruption of schools by the fishing operation results in unobserved death of the nursing young. Such terminated nursing cycles would correspond to shorter lactation periods when the incidental kill is high. Similarly, if these females subsequently ovulate, due to cessation of lactation, and become pregnant sooner than they would have if their calf had nursed to normal completion, a

higher pregnancy rate not implying increased recruitment would result.

Thus,in the early 1970's at the higher level of incidental kill, the estimated lactation periods and pregnancy rates would be expected to be larger, while more recently with the reduced kill levels these rates would be lower.

The estimates of gross annual reproductive rates under the two methods for estimating pregnancy rates are shown in Table 17 for several stocks, along with the estimates of the three quantities used in the calculation. The only statistically significant difference among estimates for stocks of a single species is between method 1 estimates for the northern and southern offshore spotted dolphins (11.7% vs 19.5%), but there is a strong possibility of seasonal bias* in the data for the latter stock because the sample was collected over a very short portion of the calendar year. The estimated proportion of sexually mature females are all lower for the more exploited stocks (northern versus southern offshore spotted and eastern versus northern versus southern whitebelly spinner). This would be expected to some degree on theoretical grounds as the average age of the population decreases under exploitation. The estimates of annual pregnancy rates are higher for the more exploited spinner stocks under both methods, but only under method 2 for spotted stocks. These trends in component values result in gross annual reproductive rates which are higher in the more exploited stocks for method 2 pregnancy rate estimates, but lower for the method 1 estimates.

3.5.4 NET REPRODUCTIVE RATES

* Examination of the timing of reproduction of southern offshore spotted dolphin after the workshop revealed strong seasonality, implying that the estimate of 19.5% is strongly biased upward.

The 1976 workshop (SOPS/79/1) estimated the net reproductive rate based on the difference between estimates of gross reproductive rates of spotted dolphin stocks near Japan and in the ETP. This estimate is rejected now based on information provided by Dr. Kasuya that the Japanese population may have been more heavily exploited than previously thought, and that there may be segregation of prepubertal dolphins into separate schools.

Estimates of natural mortality rate relative to body length for a suite of cetaceans are available in SOPS/79/37. While the regression relationship is suggestive, it is not sufficiently precise to provide much information on the rates in specific instances. Additionally, the relationship is developed for data from both baleen and odontocete cetaceans, and this pooling does not seem justifiable because of differences in the overall characteristics of the two cetacean groups. Dr. Kasuya additionally noted that the mortality rates used in this paper (SOPS/79/37) for Stenella attenuata and S. coeruleoalba are based on his work and are likely too high.

Estimates of the gross annual reproductive rates of the southern whitebelly spinner and the tentative southern offshore spotted dolphin stocks may, because of the low level of exploitation of these stocks, be used as estimates of their natural mortality rates, as discussed above. It it is assumed that these natural mortality rates also apply to exploited stocks then the difference in gross annual reproductive rate estimates (Table 17) for northern and southern offshore spotted (10.1-9.1 = 1.0), although statistically not significant at 95% levels, is an estimate of the net reproductive rate for northern offshore spotted dolphin. A similar comparison for eastern spinner and the southern whitebelly spinner dolphin (9.8-6.7 = 3.1) is an estimate of the net reproductive rate for eastern spinner dolphin.

There are several uncertainties in these two estimates, including (1) those outlined in Section 3.5.3, (2) the lack of either estimate being significantly different from zero, and (3) the lack of the two estimates being significantly different from each other. Due to these uncertainties the group feels that it is reasonable to average the two values, rounded to 2.0, and this value is used below.

Changes in the age of first pregnancy and in the pregnancy rates relative to age for the eastern and southern whitebelly spinner dolphin are described in SOPS/79/30. The age of first pregnancy is less and the pregnancy rate in young females is lower for the more heavily exploited eastern spinner. The relationship between testes weight and body length, and the frequency of relatively small testes with no sperm in the epidydimis both suggest lower male fertility in the more heavily exploited eastern spinner population.

These changes are not all consistent with expectations under the hypothesis of density dependent population regulation. Although the net reproductive rates do differ in the expected direction, the differences are small and the age specific inconsistencies suggest the possibility that the heavily exploited stocks are encountering some unexpected reproductive difficulties.

These opposing changes in rates confound interpretation of differences between estimated gross annual reproductive rates from populations of different exploitation histories and suggest, especially in light of the lack of significant differences, that a reproductive rate of zero is consistent with the available information. To reflect our concerns over such possible reproductive difficulties and over the absence of a marked difference in gross reproductive rates between the exploited and unexploited populations, we utilize this value as a lower bound in assessing the stocks.

In addition to these two values Dr. Chapman reported a value of 4% for baleen whales. No values greater than 4% have been reported for any cetaceans. This, along with the observation that baleen whales tend to have shorter periods of parental care of young than do odontocetes, suggests that the maximum possible net reproductive rate for porpoise may be in the area of 4%.

The values 0, 2 and 4 percent net reproductive rates contrasts with the range of 2 to 6 percent used in the 1976 workshop. The value of 4% used in 1976 was obtained as the difference between the estimated gross annual reproductive rate for offshore spotted dolphin in the eastern Pacific and the corresponding estimate from the western Pacific (Japanese) spotted dolphin stock. The interval of 2 to 6 was obtained by assuming the western Pacific value was known without error and allowing for the estimated variance of the eastern Pacific value. The former upper limit of 6% is abandoned here as being without supporting evidence.

3.6 METHODOLOGY FOR ESTIMATING PRE-EXPLOITATION POPULATION LEVELS

The techniques used are fully described in documents SOPS/79/11, 12, and 18; the latter also present preliminary pre-exploitation population estimates based on preliminary kill and 1979 population level estimates prepared in advance of the meeting. The method for estimating pre-exploitation sizes is based on a simple recursive relationship, assuming that the population size in the next year is simply the present population size, minus the present incidental kill, plus the net number of individuals recruited to the

population during the year. This latter quantity is taken to be the net reproductive rate (births less natural deaths) times the number of animals actually reproducing in a given year. The number reproducing is approximated by assuming reproduction occurs half-way through the fishing season, so it is the present population reduced by one half the incidental kill for that year. This model is used in reverse to estimate the population size in a previous year based on the present population size. The annual sequential equation resulting from this model is

$$N_{t+1} = \frac{N_t + 1/2\ K_{t+1}}{1 + R_{t+1}} + 1/2\ K_{t+1}$$

with the time index t running backwards (that is time t+1 occurrs one year prior to time t).

This leads to estimating the population size (N_ℓ) in year ℓ:

$$\hat{N}_\ell = \frac{\hat{N}_{79}}{\prod_{j=78}^{\ell} (1+R_j)} + \sum_{j=78}^{\ell} \frac{K_j(1+R_j/2)}{\prod_{i=j}^{\ell} (1+R_i)}$$

where $\hat{N}_{79}$ is the previously estimated 1979 population, K denotes the sequence of estimated annual kills up to time 1978, and R denotes the net recruitment rate in any year.

The chief change from the procedure used in the 1976 workshop (SOPS/79/1) is that the recruitment rate R_ℓ in any year ℓ, instead of being a sequence of annual values, is calculated using the density dependent relationship (SOPS/79/18):

$$R_\ell = R_{max} \left(1 - \left(\hat{N}_\ell / \hat{N}_p\right)^Z\right)$$

where $\hat{N}_p$ is the estimated population size in the year prior to exploitation (p), R_{max} is the maximum net recruitment rate and Z is the density dependent exponent. The value of Z corresponds to the MNP level as described below. Since $\hat{N}_p$ is not known until the series has been calculated, an iterative procedure is required.

The statistical properties of the estimate of $\hat{N}_p$ and the ratio $\hat{N}_{79}/\hat{N}_p$ are examined in detail in documents SOPS/79/11, 12, and 18; methods of calculating the variances are developed there and were available to the meeting in established computer programs. Tests of the sensitivity of the estimates of $\hat{N}_p$ to the values of $\hat{N}_{79}$, K_t and R_{max} show that they are most sensitive to N_{79}, then to K_t and least sensitive to the reproductive rates.

Examination of the shape of the sampling distributions shows that if $\hat{N}_{79}$ is symmetrically distributed, then this applies also to $\hat{N}_{59}$. The resulting sampling distribution of the ratio $\hat{N}_{79}/\hat{N}_{59}$ would then be skewed left.

The model does not provide for any time lag in recruitment, and should therefore be used with population estimates including all age groups. While the counts on which the population estimates are based may have missed some calves, the bias arising in this way is negligible compared to the other errors in the estimates. There could be a lag in the effects of density-dependent changes in the net rate of recruitment, if these are due, for example, to changes in the age at maturity. Similarly, there could be a lag in response if reproductive rates are determined by the nutritional level during early years of life. In the absence of relevant data the group agrees that it is not possible to allow for such a time lag in the model.

In the calculation of the pre-exploitation abundance estimates, estimates are obtained of the stock size in each year. The general form of these sequences provide our best estimates of the history of each stock; the recent years of those sequences of estimates indicate our best understanding of the population's behavior under the current management regime.

For each stock a current replacement incidental yield (RY) can be estimated as

$$\hat{RY} = \hat{N}_{79} R_{max} \left(1 - \left(\hat{N}_{79} / \hat{N}_p\right)^Z\right)$$

This is the number of animals which if killed, assuming complete randomness of the kill with respect to age and sex, would result in the population size being the same the following year.

Estimates of the parameters in these equations are obtained from Sections 3.3, 3.4 and 3.5. Present abundance estimates ($\hat{N}_{79}$) for each stock are obtained from Table 7. Two values for each stock are considered. The variances of the unadjusted estimates given in that table are used in determining the variances of the estimates of N_{59}. Variance estimates are not available for the adjusted estimates. The annual estimates of incidental kill ($\hat{K}_j$) are taken from Table 15. Variances for these estimates are not available, although estimates of the variance for some of the components of the kill have been calculated. Variance estimates are available for the direct kill of all fleets from 1959 to 1972 (SOPS/79/15), for the direct U.S. kill by stock (Table 10), and for the direct non-U.S. kill for all stocks combined (Table 12).

Due to the overall estimation techniques, the individual $\hat{K}_j$ are not statistically independent. Formulas are given in SOPS/79/18 for the variance

of $\hat{N}_p$ accounting for non-dependent kill estimates, utilizing estimates of the covariances among all the kill estimates. The covariances among the direct kill by all fleets for 1959 to 1972 are given in SOPS/79/15, but those for total kill for 1959 to 1972 (including serious injury) and for 1973 to 1978 are not available.

The best that can be done at this point is to: (1) assume that the estimated proportion seriously injured have zero variance as applied to the years 1959 to 1972 ; (2) approximate lower bounds of the variances of the estimates of the total kill for each stock for 1973 to 1978 by assuming the same coefficient of variation as observed for the direct U.S. kill for those years; and (3) assume that the kill estimates for 1973 to 1978 are independent of each other and of the kill estimates for 1959 to 1972 (Section 3.4.7). Such variances would probably not be seriously in error for item (1), but would be increasingly in error in more recent years due to item (2), where the non-U.S. kill constitutes a larger fraction of the total. The errors associated with assuming independence (item (3)) are unknown, but clearly result in underestimates of the variances of estimates of pre-exploitation abundance. Making these assumptions, minimal estimates of the standard deviations for 1973 to 1978 are shown in Table 18, and of the variances and covariances for 1959 to 1972 are shown in Table 19. These figures are used in the assessments of the status of the stocks.

The parameter R_{max} is estimated by the net reproductive rates given in Section 3.5.4. It should be noted that this equivalence is not strictly correct unless the populations for which estimates are available have been reduced to near zero abundance. This is because the net reproductive rate actually achieves the value R_{max} at zero population levels. The error due to this is small for the eastern spinner population as it has apparently been

reduced to very low levels. For the offshore spotted population the error caused by this is somewhat larger, but well within our overall uncertainty about reproductive rates. Variances for these parameter estimates are not available; three values of R_{max} (0, 0.02, and 0.04) will therefore be used.

The parameter Z corresponds to the level of maximum net productivity (MNPL) as (SOPS/79/18):

$$MNPL = \frac{N_p}{(1+Z)^{1/Z}}$$

Values of MNPL of 65, 72.5 and 80% of carrying capacity (see Section 2.3.1) give Z values of 3.5, 6.0, and 11.5 respectively. These three values will be used alternatively in the estimation of pre-exploitation abundance.

The year at which exploitation started varies among stocks, with the earliest year being 1959. For each stock the year in which exploitation started is taken to be that year in which kills were first estimated. Equivalently one can consider the year 1959 as the year exploitation started for all stocks, with the incidental kill levels at zero for a period of years.

4.0 STATUS OF PORPOISE STOCKS

The assessments of the stocks presented in this section are based on point estimates. They are further based on the information available to the workshop and assume that there are no major systematic biases in the estimates of incidental kill, population size, and reproductive rates. They are also subject to the uncertainties imposed by statistical error. To the extent that we've explicitly estimated variances, these reflect, for the most part,

sampling errors. In addition to the above, there are concerns over the assumptions in the models. Nevertheless, the workshop believes that the assessments represent significant improvements over those contained in the 1976 workshop report (SOPS/79/1) and should now be the basis of further management decisions with respect to these stocks.

4.1 PARAMETER VALUES USED

The workshop participants agree that it is necessary to consider several alternative calculations of the pre-exploitation population levels. These alternatives are based on two estimates of the current population sizes, (N_{79}), three estimates of the maximum net reproductive rate (R_{max}), and three values of the parameter Z, which determines the shape of the net productivity curve and simultaneously the population size at which MNP occurs. The year corresponding to pre-exploitation depends on the particular population or stock being considered, as not all stocks have been involved since the beginning of the fishery.

Each calculation of pre-exploitation abundance yields an estimate of the ratio of the current stock level (N_{79}) to the pre-exploitation population level (N_p). Each ratio should be compared to the MNP level coresponding to the value of the parameter Z used in that calculation to determine where the estimated status of stock is in relationship to the MNP level.

For each calculation of the pre-exploitation population size the time series of population estimates in the intervening years is obtained. These time series do not change much in general form between the two values of present population size and among the different values of MNPL. However, they

do differ substantially for the recent years for the differences in the value of R_{max}, with the direction of the changes in population size in recent years, depending directly on the magnitude of R_{max}. Unfortunately, we have inadequate information on the value of R_{max} to choose among the three indicated values of 0, 0.02 and 0.04.

In the figures (7 to 16) accompanying the following discussion of each stock, these sequences of population size are shown for unadjusted present population estimates, for MNPL of 0.725, and for R_{max} of 0, 0.02 and 0.04 as examples only. We are not suggesting that either the unadjusted population estimates or the 0.725 value for MNPL are preferable to other values considered by the participants. Selection of either the adjusted population estimates or alternative values of MNPL would not change these figures substantially in most cases.

The replacement yields (RY) are similarly dependent on R_{max}, but also are jointly dependent on the MNP level (the parameter Z), and the ratio of present to pre-exploitation abundance. The group cannot select any particular value of the replacement yield within the range of possible parameter values described above.

The workshop participants note various concerns, expressed above, with regard to both the assumptions in these calculations and the parameter estimates. Also, the group notes (Section 3.4.6) the possibility that because of the impact of the fishing (the chase, encirclement, etc.), the animals are stressed in such a way that reproduction or survival of young calves may have been seriously reduced. This applies to all stocks, but is most likely to have an effect on the stocks that have been set on most frequently, particularly the spotted and spinner stocks. These concerns are not repeated in the individual status of stocks reviews given below, but it should be kept

in mind that it has not been possible to quantify these effects and that the assessments of the status of stocks may be in error for this lack.

4.1.1 INTERPRETATION OF RANGES OF VALUES

The use of a range of values for R_{max} and MNPL (Z) affects the basis for managerial decisions in two ways. First, since the OSP has been defined by the NMFS (Appendix 3) as being within the range extending from the MNP level (which depends on Z) up to the carrying capacity, the value of the MNP level which has been used in each calculation constitutes the level against which the estimated current relative population has to be compared in determining what the management objective should be. Second, both the MNP level and R_{max} will influence the estimated initial population size, and therefore the proportion which the present population size constitutes of the original.

Thus, for a given stock the relation of estimated stock size to OSP may vary between calculations according to the values of MNPL and R_{max} used. It is therefore useful to examine the manner in which the relation between estimated population level and the lower bound of OSP (=MNP level) varies with values of R_{max} and the MNP level. Figure 6 shows for three different stocks, using the unadjusted population estimates, the estimated current population size as a proportion of pre-exploitation population size (N_{79}/N_p) plotted against the corresponding MNP level. The solid line in the figure indicates the conditions under which the relative current population level is equal to the MNP level. Any calculation giving a point above this line denotes a stock for which the current stock level falls above the lower limit of the OSP range.

For each stock the crosses indicate assessments made with R_{max}=0.04, and the solid circles assessments with R_{max}=0.02. The broken line indicates assessments with R_{max}=0.0. This latter relative population level is independent of MNP level, and is the lowest ratio which can be obtained with the given current population and kill series.

Figure 6 shows that in the calculations the ratio of current population to pre-exploitation population size increases slowly with MNP level, but much more slowly than the MNP level itself. This ratio, however, increases quite rapidly with R_{max}. This indication of the behavior of the calculations of population levels enables statements to be made of the effect on the basis for management if the true values of R_{max} and MNP level had been other than those calculated.

In the example, calculations would have to be made for the eastern spinner with an extremely high (probably impossibly high) R_{max} and a very low MNP level to obtain an assessment within the OSP range. On the other hand, for the southern spotted dolphin, only MNP levels above 0.93 together with a very low R_{max} would give an assessment below the OSP range.

An intermediate condition is represented by the northern whitebelly spinner dolphin. Here the values used give assessments which straddle the lower boundary of the range of OSP. The specific parameter values used in the assessments clearly have a very critical effect on the practical implications of the results for this stock. It is still possible, however, to make useful statements about the effect of parameter values beyond those tested. If, for instance, the MNP level was below 0.65 this stock would be assessed as being within the OSP range whatever the value of R_{max}, while above an MNP level of 0.85, values of R_{max} much greater than 0.04 would be required to move the assessment into the OSP range.

This analysis has examined the behavior of the point estimates of the populations over a range of values of R_{max} and Z. It has ignored the uncertainties in these estimates due to sampling errors or possible biases in assumptions about, for example, the unknown kill. The same principles will, however, still apply when these errors and biases are taken into account. Any change in the model would require a new analysis of the effects of changing the appropriate parameters.

4.1.3 DIFFERENCES BETWEEN THE 1976 AND 1979 ASSESSMENTS

The bases of the estimate of pre-exploitation abundance, and, thus, of the stock assessments, are the estimates of present abundance. Although the estimates of abundance in 1979 are substantially lower for most stocks than in the 1976 assessment, this should not be construed to be an indication of large stock decreases between these years. The 1976 estimates (SOPS/79/1) were based on data then available and a series of assumptions which were listed in that document. With new data in the years subsequent to 1976, many of these assumptions have been addressed. The result is a new and improved estimation procedure documented in SOPS/79/29. The differences in methodology between the 1976 and 1979 assessments of abundance were discussed in SOPS/79/29 and are reiterated here.

The 1979 estimate utilized aerial observer estimates of school size which are corrected for the bias introduced by a higher probability of larger schools being sighted; the 1976 assessment relied on observer and crewmember estimates of school size from tuna vessels, uncorrected for sighting bias. The 1979 density of schools is estimated using aerial and research vessel

data; the 1976 assessment used a combination of research vessel and tuna vessel data for some species, and tuna vessel data alone for others. The 1979 estimates correct the species distributions to account for differential sighting rates of tuna vessels; the 1976 assessment did not correct for this. The 1979 estimates extrapolate the aerial data with appropriate correction factors to areas covered sparsely by research vessels; the 1976 assessment extrapolated to these areas with essentially no survey coverage. The 1979 geographic ranges of the most abundant species are estimated to be very similar to the larger of the ranges used in 1976.

The net effect of all of these factors is that the 1979 abundance estimates are in general lower than those obtained for 1974 in the 1976 workshop. Workshop participants agreed to make it clear that these differences are mainly the result of better estimation procedures. In contrast, the best estimates of the actual changes in population sizes between 1974 and 1979 can be seen in Figures 7 to 16.

4.2 SPOTTED DOLPHIN

4.2.1 COASTAL SPOTTED STOCK

Although this stock is distinguishable morphologically and ecologically from the offshore stocks, identification of individuals is usually not possible without careful examination. For this reason the kill from this stock is probably underestimated. The workshop agreed that kills from this stock were probably small prior to 1973, and that this year could be used as

pre-exploitation for the purposes of the back calculation and the evaluation of status of stocks. This stock is estimated to be at 97 to 100 percent of the 1973 abundance level and falls within the OSP range.

Estimates of quantities used in this assessment according to the several alternatives are shown in Table 20a. The annual replacement yield is between 0 and 418 animals.

The estimated population sizes by year for this stock are shown in Figure 7 for selected combinations of parameter values.

4.2.2 OFFSHORE SPOTTED STOCK(S)

The group agreed to consider this population alternatively as one or two (southern and northern) stocks. Information on kills from the putative southern offshore spotted stock was available from 1973 to 1978. In view of the lack of fishing effort in the area occupied by the southern stock prior to 1973, it was agreed that kills for the 1959-1972 period would have been zero. Thus, for this stock 1973 is taken as pre-exploitation. For the northern offshore stock, 1959 is taken as pre-exploitation.

Estimates of the quantitites used in this assessment are shown in Tables 20b and 20c for northern and southern offshore spotted stocks. Table 20b shows that the northern offshore spotted dolphin is at 34 to 55 percent of its 1959 level, which is below the OSP range. Table 20c shows that southern offshore spotted dolphin is at 92 to 98 percent of the 1973 level, which would imply that it is within the OSP range.

The relationship between the ratio of present to pre-exploitation population size and the MNP level under various parameter combinations is

shown in Figure 6 for the southern stock. The annual replacement yields are between 0 and 110,322 animals, and between 0 and 5,173 animals for the northern and southern stocks respectively.

Table 20d gives estimates for the offshore spotted stock treated as a unit stock. The present level is 39 to 62 percent of the 1959 level; and the combined offshore spotted stock is below the range of OSP. The annual replacement yield is between 0 and 114,900 animals.

The time sequences of population sizes are shown in Figures 8, 9 and 10 for the northern, the southern and the combined offshore spotted stocks respectively. The effects of recent kills are shown in the figure insets for the three R_{max} values considered.

4.3 SPINNER DOLPHIN

4.3.1 EASTERN SPINNER STOCK

The eastern spinner stock in 1959 is taken as being pre-exploitation. The stock is at 16 to 20% of its 1959 level and is below the range of the OSP (Table 20e). The replacement yield is between 0 and 12,216 animals.

The relationship between the ratio of present to pre-exploitation population size and the MNP level under various parameter combinations is shown in Figure 6. Figure 11 shows the estimated history of the population.

4.3.2 NORTHERN WHITEBELLY SPINNER STOCK

The northern whitebelly spinner stock was apparently first involved with the fishery as the vessels started operating further offshore in 1969. This year is taken as pre-exploitation.

The stock is at 62 to 81 percent of its 1969 level, and is near the lower bound of OSP (Table 20f). The replacement yield is between 0 and 14,643 animals. The relationship between the ratio of the present to the pre-exploitation population size and the MNP level under the various parameter combinations is shown in Figure 6. Figure 12 shows the estimated abundance history of the population.

The status of the northern whitebelly stock was discussed at length. In particular, the reservations expressed earlier in the report were reviewed. The large standard errors associated with the ratio estimates are noted. The workshop participants believe that the northern whitebelly stock is near the lower limit of the proposed OSP range. Further research on this stock is needed.

4.3.3 SOUTHERN WHITEBELLY SPINNER STOCK

The southern whitebelly spinner stock in 1973 is taken as pre-exploitation, for the same reasons given for the southern offshore spotted dolphin stock.

The stock is at 85 to 94 percent of the 1973 level and this implies that it is within the OSP range (Table 20g). The replacement yield is between 0 and 4,421 animals. Figure 13 shows the abundance estimated history of the

population.

4.4 COMMON DOLPHIN

The group notes that the adjusted and unadjusted population estimates vary more for the common dolphin than for the other species (Table 7). In part, this difference may be due to the lesser interest of the fishery in common dolphins, which have not been associated with large tuna schools to the same degree as the spotted and spinner stocks. Thus, the proportion of common dolphins sighted in the aircraft surveys and from tuna vessels varies greatly. Attempts have been made to correct for this, but large uncertainties remain in these population estimates.

The participants agree that due to the lack of data the northern tropical and Baja neritic stocks should be combined for management purposes at this time. The Baja neritic stock has been very infrequently involved in the fishery and the temperate and southern tropical stocks have not been affected by the purse seine operations

4.4.1 NORTHERN TROPICAL AND BAJA NERITIC COMMON STOCKS

The year 1973 is taken as pre-exploitation for these stocks, treated here together. The stock is at 95 to 100 percent of its 1973 level and is classified as within the OSP range (Table 20h). The replacement yield is between 0 and 747 animals. Figure 14 shows the estimated history of the population.

4.4.2 CENTRAL TROPICAL COMMON STOCK

The central tropical common dolphin stock has apparently been involved with the fishery since 1959, although the kills in the earlier years were quite small. The stock is estimated at 86 to 100 percent of its 1959 level and is classified within the rante of OSP (Table 20i). The replacement yield of the stock is between 0 and 4574 animals. Figure 15 shows the estimated abundance history of the population sizes.

4.5 STRIPED DOLPHIN

We note that, as for the common dolphin, the adjusted and unadjusted present population sizes estimates differ substantially. The main affected stock involved with the fishery is the central tropical; the other stocks have been only slightly involved, if at all, and can be assumed to be within the range of OSP.

4.5.1 CENTRAL TROPICAL STRIPED STOCK

The central tropical striped dolphin stock has been involved with the fishery since 1973. The stock is estimated at 94 to 99 percent of its 1973 level (Table 20j). The replacement yield is between 0 and 349 animals. Figure 16 shows the estimated abundance history of the population sizes.

4.6 OTHER STOCKS

Estimates of stock size of other species were given in Table 8. It was noted there that these are probably underestimates. Further, because of the various associations of these animals with the larger stocks and of the different areas occupied, it is probable that some of these stocks are more seriously underestimated than others. The kills for these species as estimated in recent years are shown in Table 15. It is evident that the fishery has not had a substantial impact on these stocks and hence they are estimated to be within the range of OSP.

LITERATURE CITED

1. Au, D. and W. Perryman. in prep. Dolphin schools and their response to an approaching ship.

2. Chapman, D.G. in press. Evaluation of marine mammal models. In C.W. Fowler and T.D. Smith (eds.) Dynamics of large mammal populations. J. Wiley and Sons.

3. Evans, W.E. 1975. Distribution, differentiation of populations and other aspects of the natural history of Delphinus delphis Linneaus in the northeastern Pacific. Ph.D. dissertation, Univ. of Calif., Los Angeles. 143 pp.

4. Fowler, C.W., W.T. Bunderson, M.B. Cherry, R.J. Ryel and B.J. Steele. 1978. Comparative population dynamics of large mammals: a search for management criteria. Final Report, Contract No. MM7AC013, U.S. Marine Mammal Commission.

5. IATTC. 1979. The Bi-Monthly Report July-August of the Inter-American Tropical Tuna Commission.

6. McCullough, D. 1979. The George Reserve deer herd: population ecology of a K-selected species. U. Mich. Press.

7. Perrin, W.F. 1975. Variation of the spotted and spinner porpoise (genus Stenella) in the eastern tropical Pacific and Hawaii. Bull. Scripps Inst. Oceanography, Univ. of Calif. 206 pp.

8. Richie, Charles R. 1976. C.A. No. 74-1456 and C.A. No. 75-0227, memorandum of opinion U.S. District Court, District of Columbia. May 11, 1976.

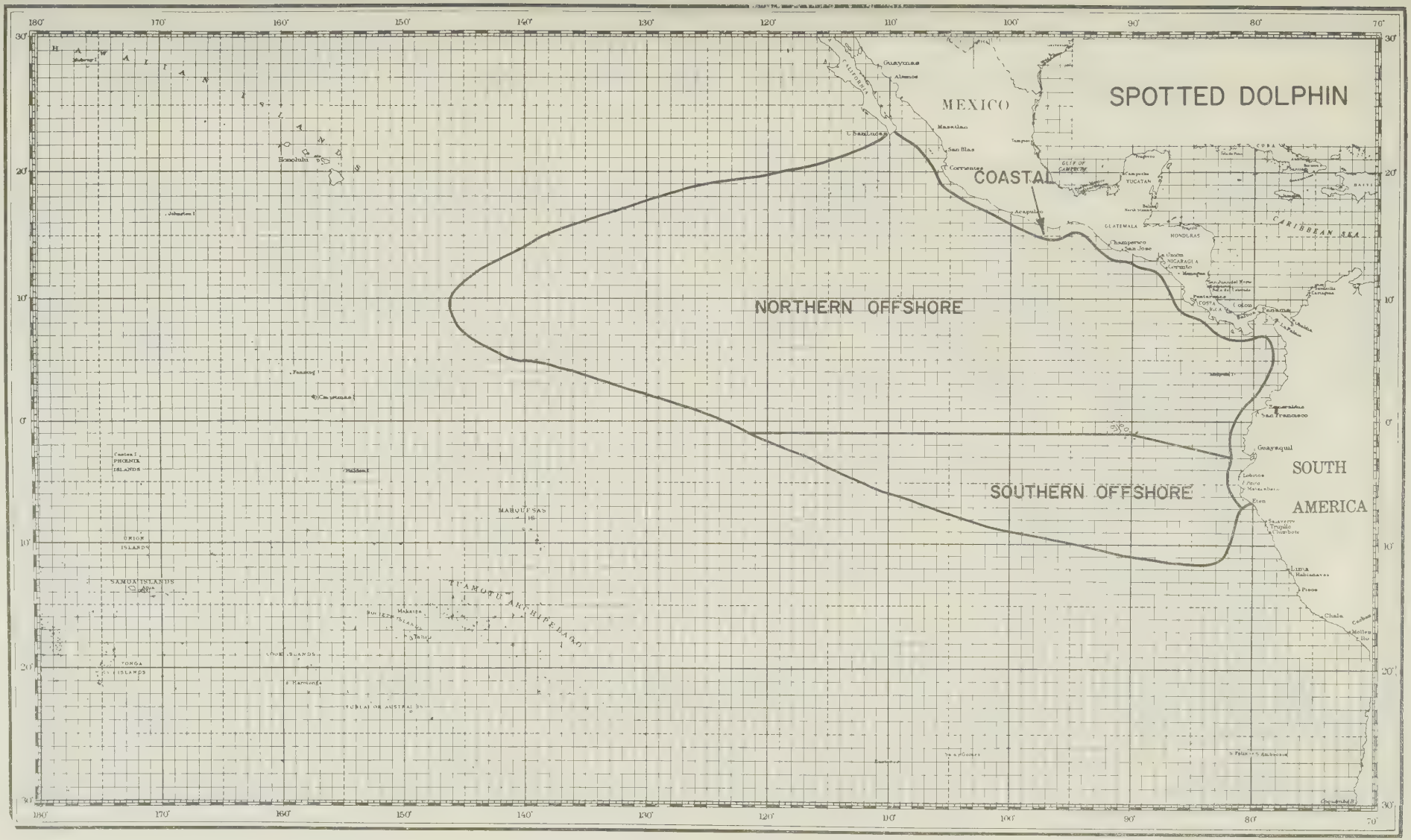


Figure 1. Distribution of the several stocks of spotted dolphin, Stenella attenuata, in the eastern Pacific Ocean.

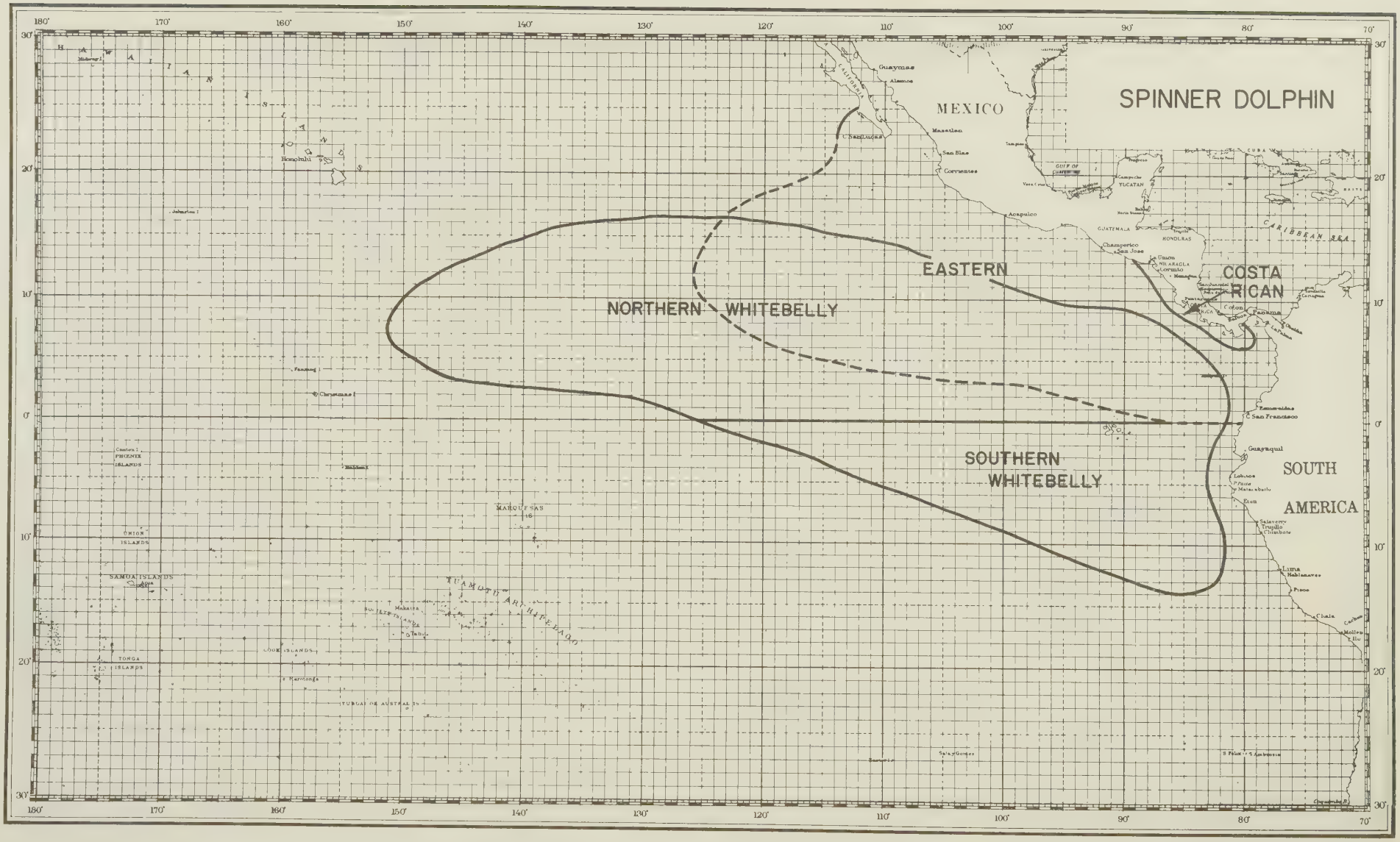


Figure 2. Distribution of the several stocks of spinner dolphin, Stenella longirostris, in the eastern Pacific Ocean.

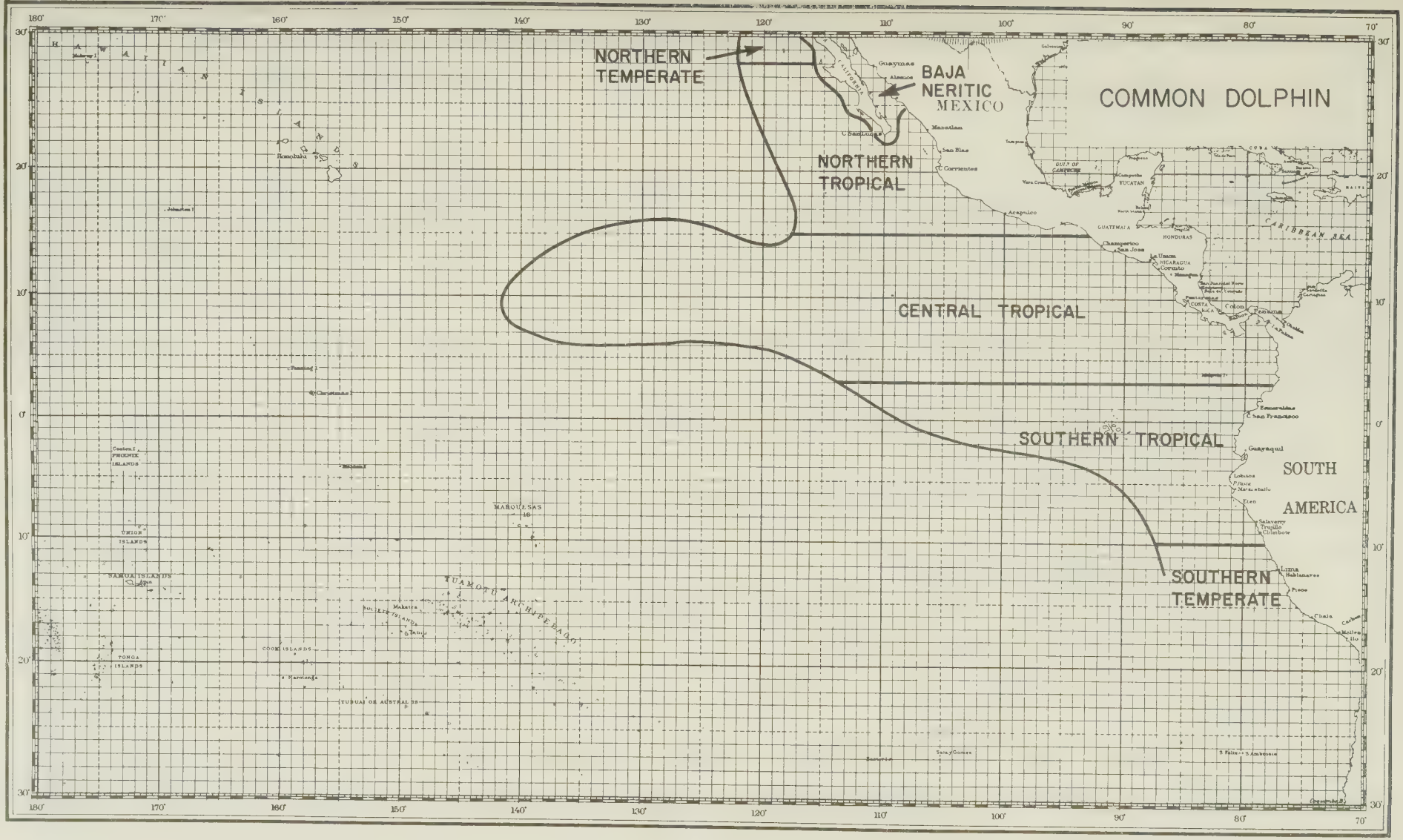


Figure 3. Distribution of the several stocks of common dolphin, Delphinus delphis, in the eastern Pacific Ocean.

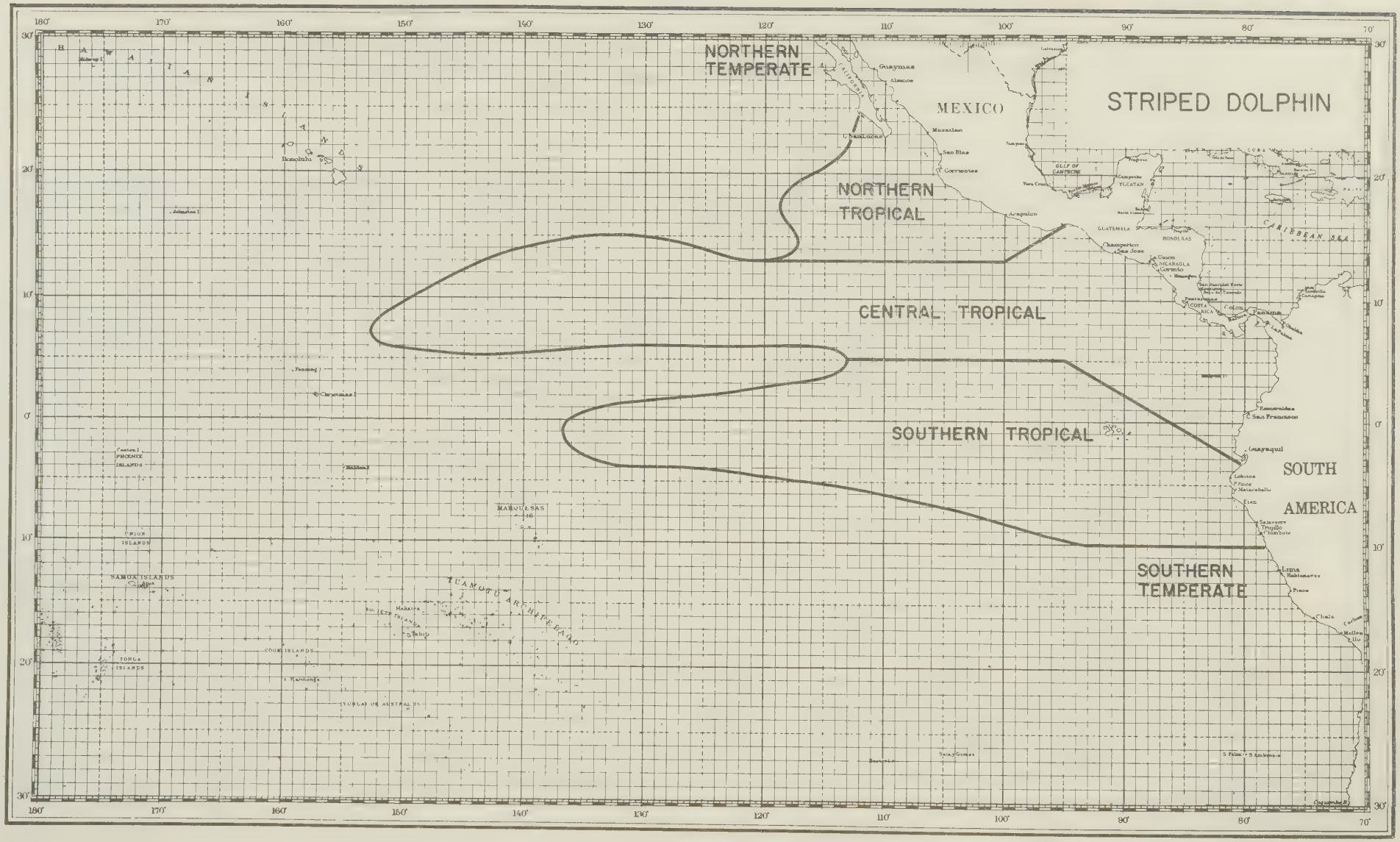


Figure 4. Distribution of the several stocks of striped dolphin, Stenella coeruleoalba, in the eastern Pacific Ocean.

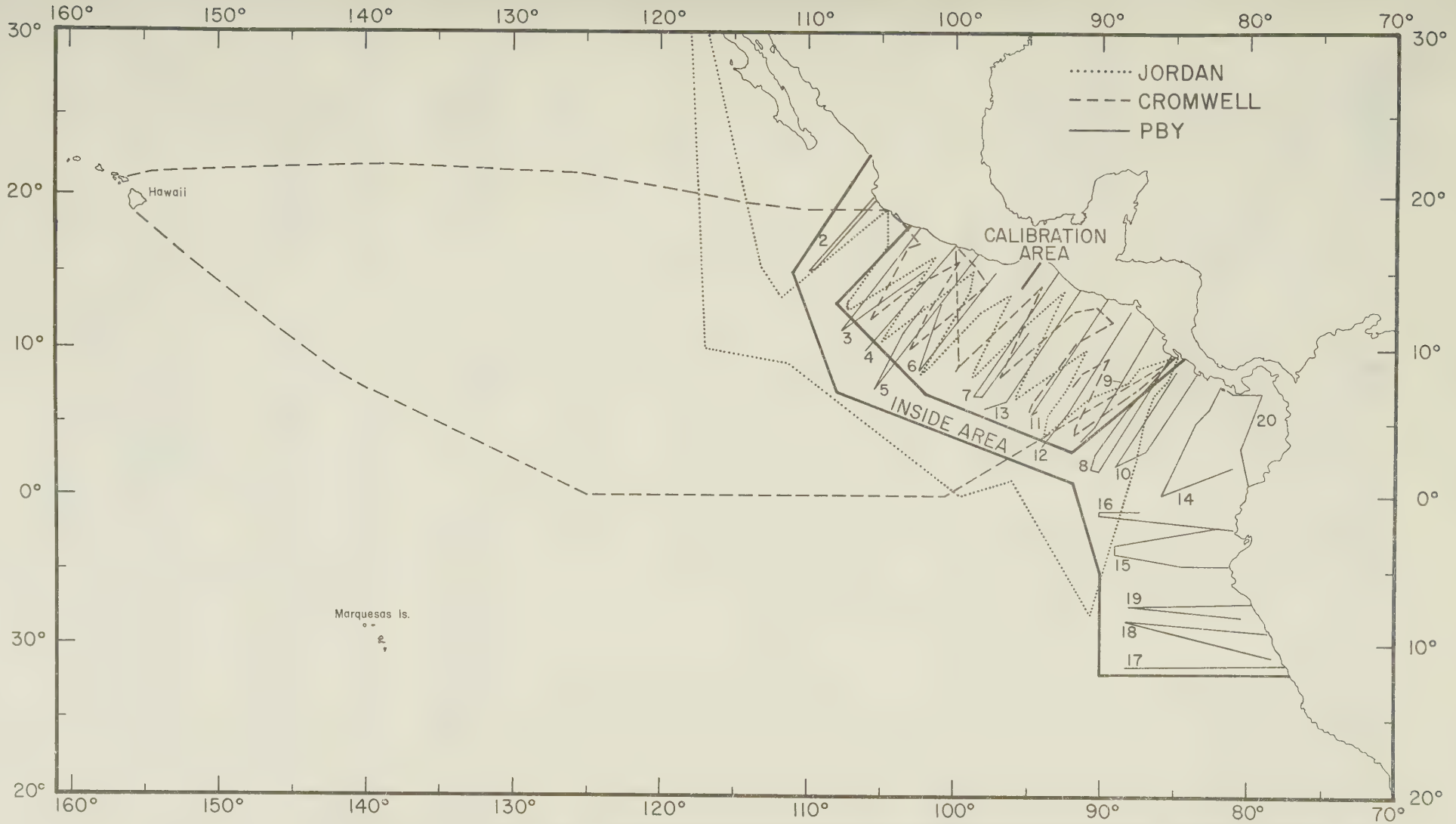


Figure 5. Ship and aircraft survey tracks used in the 1979 porpoise survey.

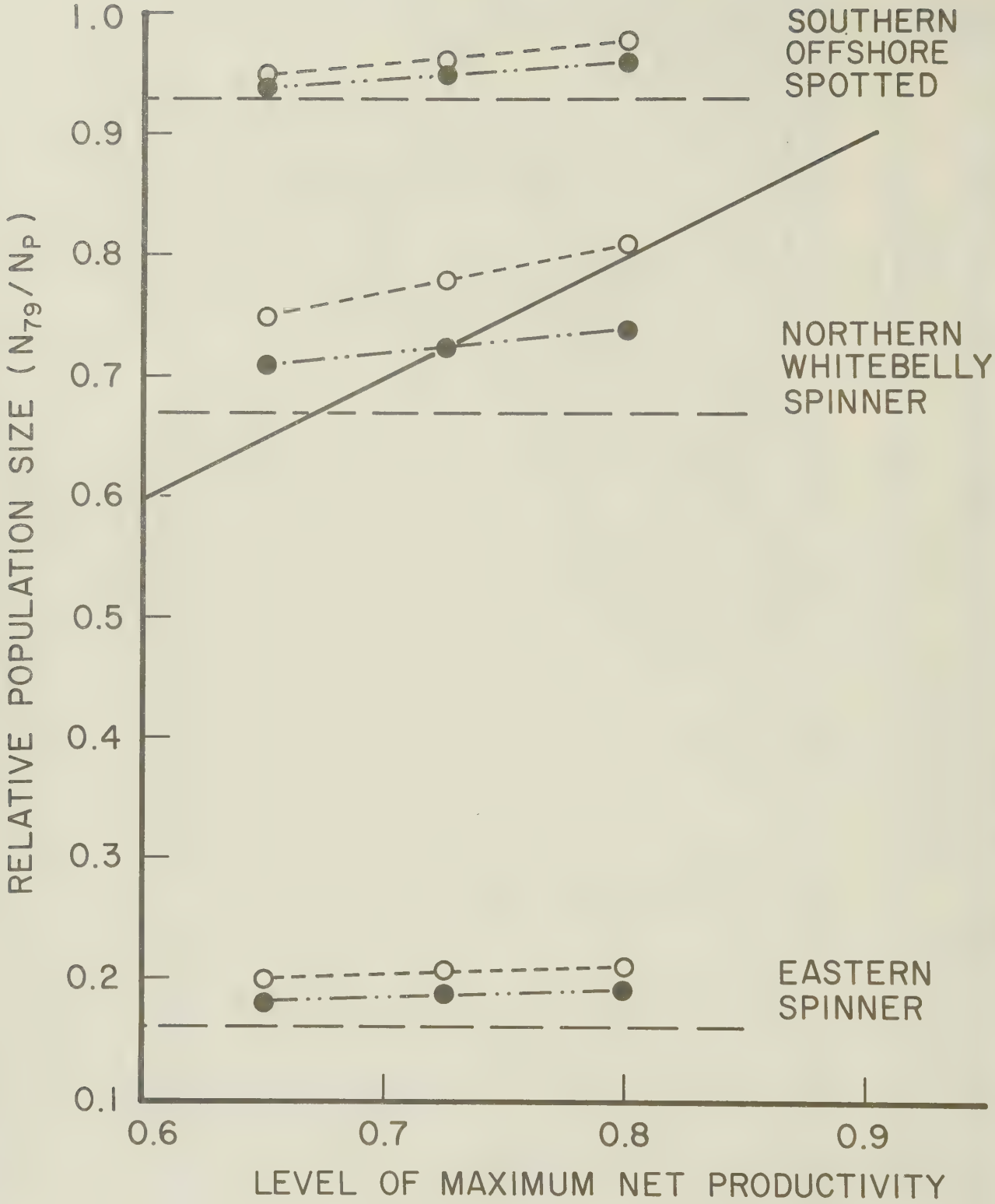


Figure 6. Estimated current population level as a proportion of pre-exploitation level (N_{79}/N_p) plotted against the corresponding MNPL, for 3 stocks and 3 values of R_{max}.

Figures 7 thru 16

Estimated population size over time for the several porpoise populations, using the unadjusted estimates of population size, MNP level of 72.5% of pre-exploitation abundance, and maximum net reproductive rate estimates of 0% (circle), 2% (square) and 4% (triangle). All graphs include zero abundance to illustrate the general magnitude of the reductions in population size which have occurred; inset graphs show the estimates of abundance for 1976 to 1979 on an expanded abundance scale to illustrate the recent history of the populations. The particular abundance estimates and MNP level used were selected for illustratuve purposes only, and do not indicate preferred or most likely values.

Figure 7 Coastal spotted dolphin

Figure 8 Northern offshore spotted dolphin

Figure 9 Southern offshore spotted dolphin

Figure 10 Combined northern and southern offshore spotted dolphin

Figure 11 Eastern spinner dolphin

Figure 12 Northern whitebelly spinner dolphin

Figure 13 Southern whitebelly spinner dolphin

Figure 14 Northern tropical common dolphin

Figure 15 Central tropical common dolphin

Figure 16 Central tropical striped dolphin

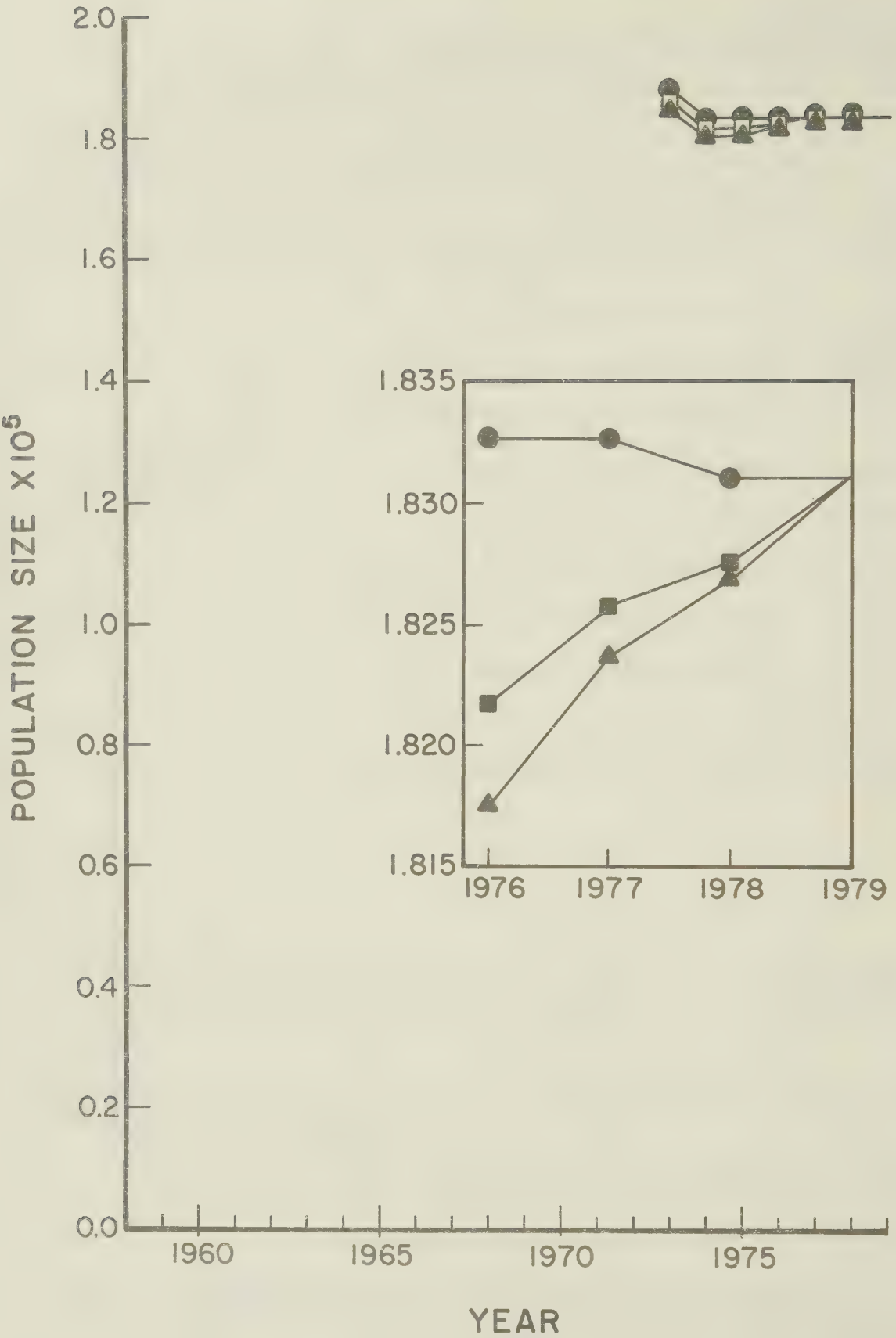


Figure 7. Coastal spotted dolphin.

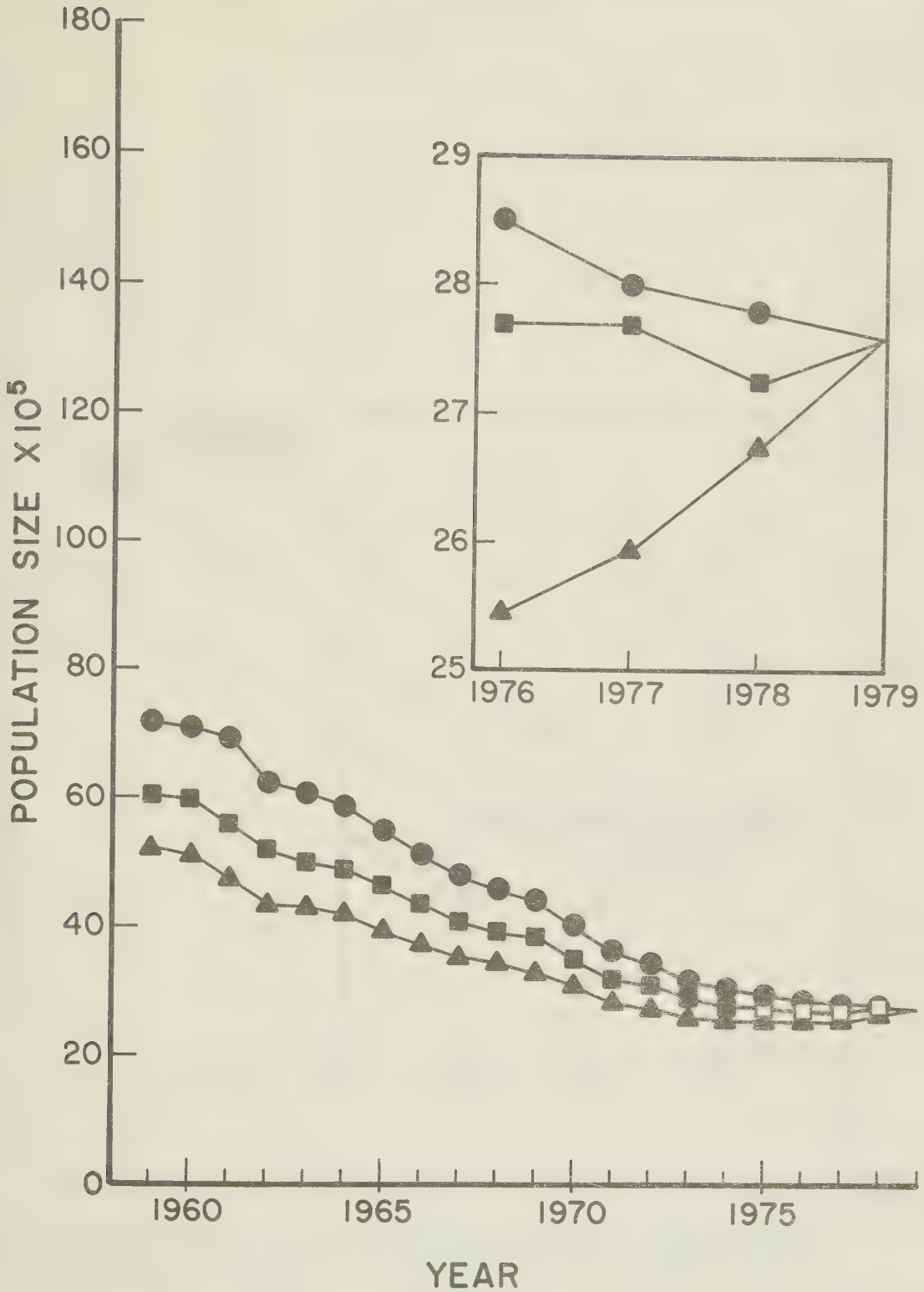


Figure 8. Northern offshore spotted dolphin.

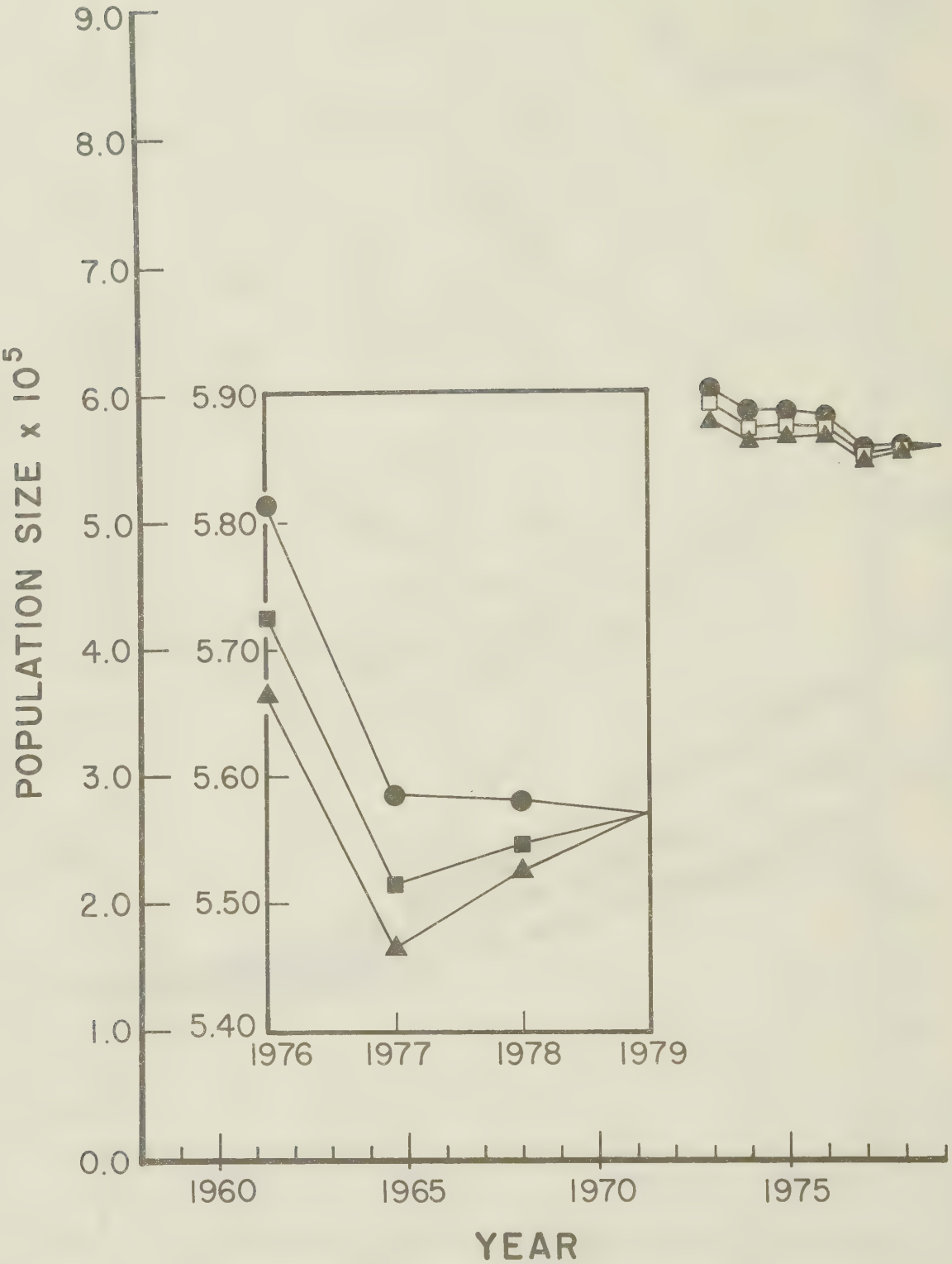


Figure 9. Southern offshore spotted dolphin.

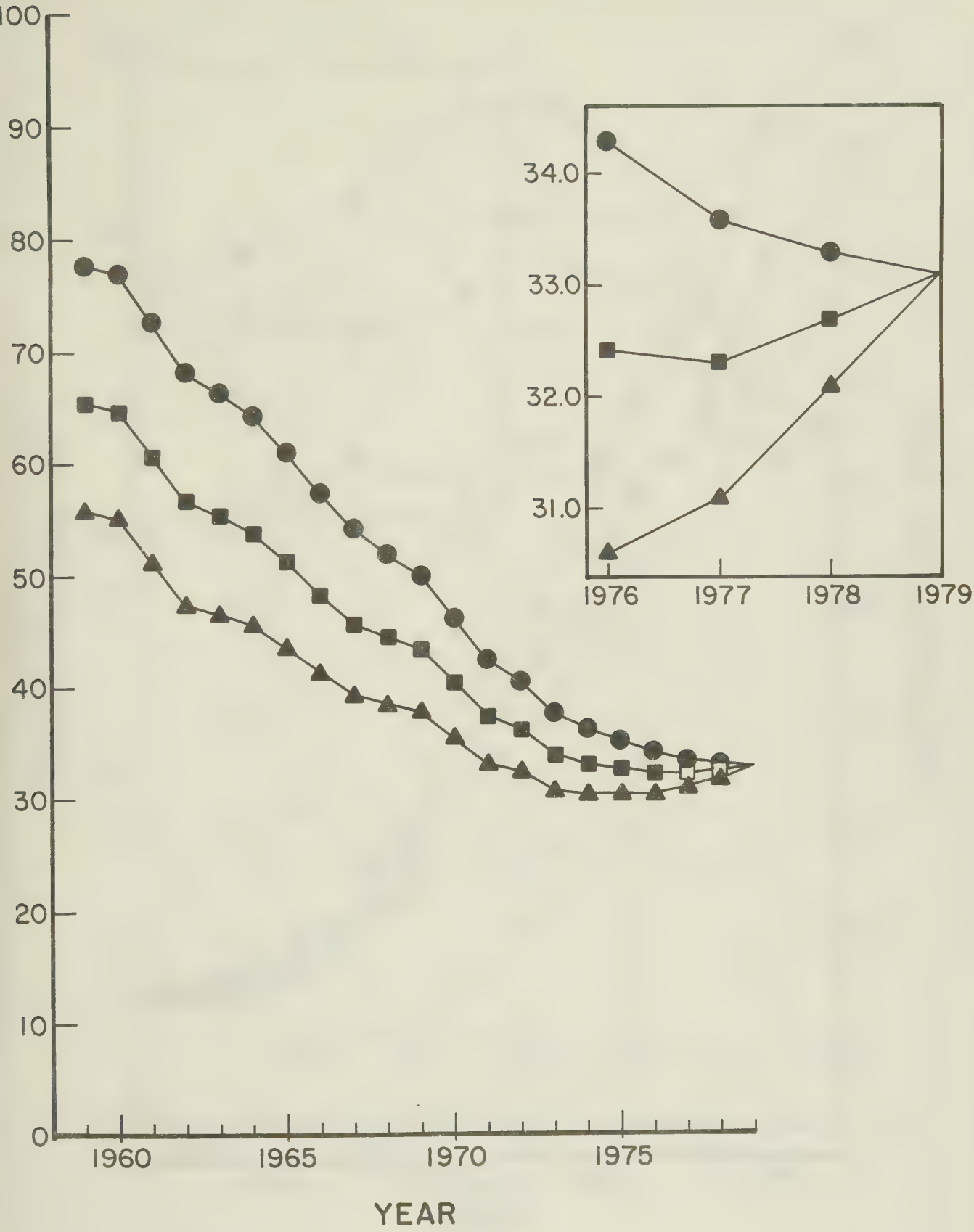


Figure 10. Combined northern and southern offshore spotted dolphin.

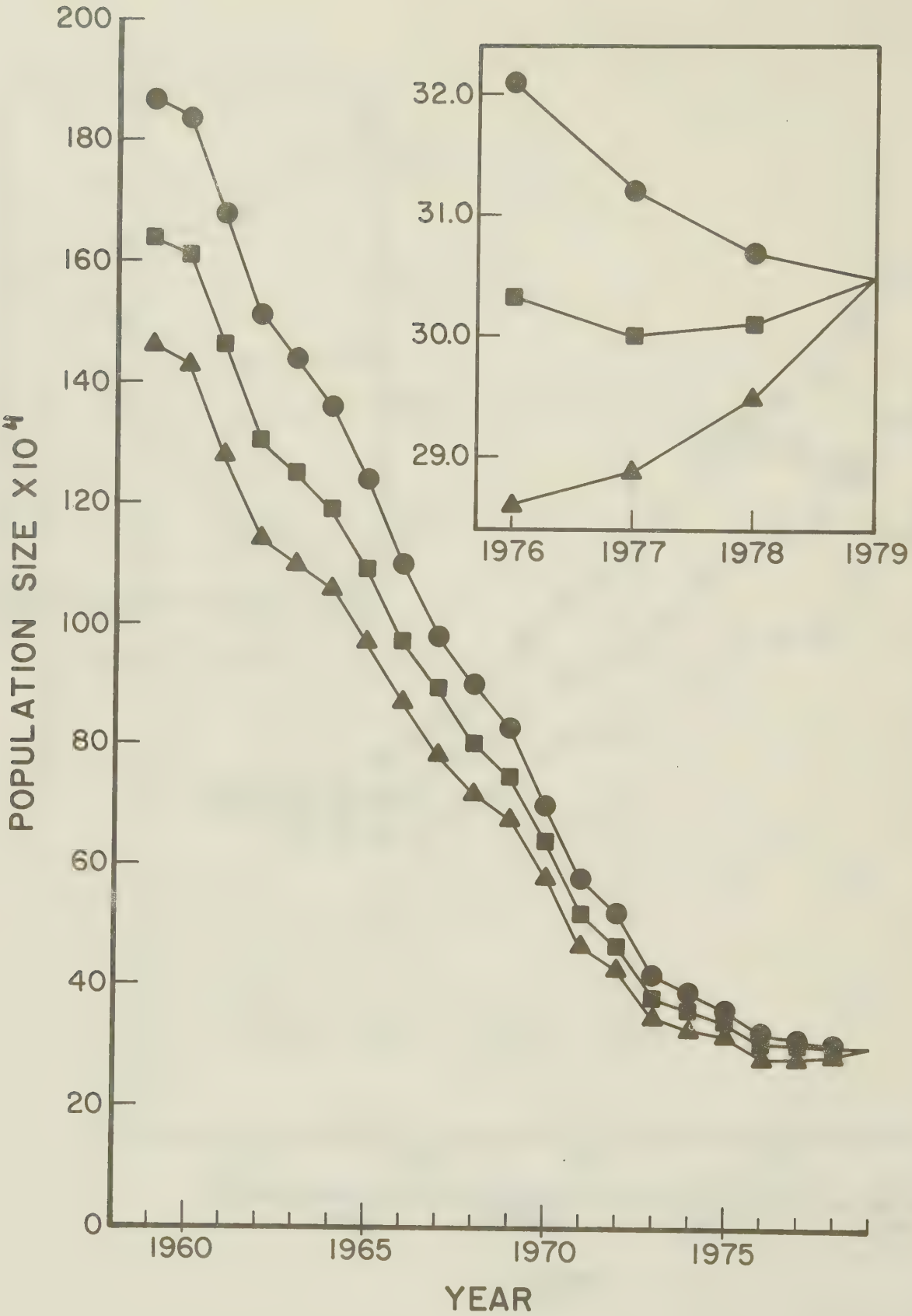


Figure 11. Eastern spinner dolphin.

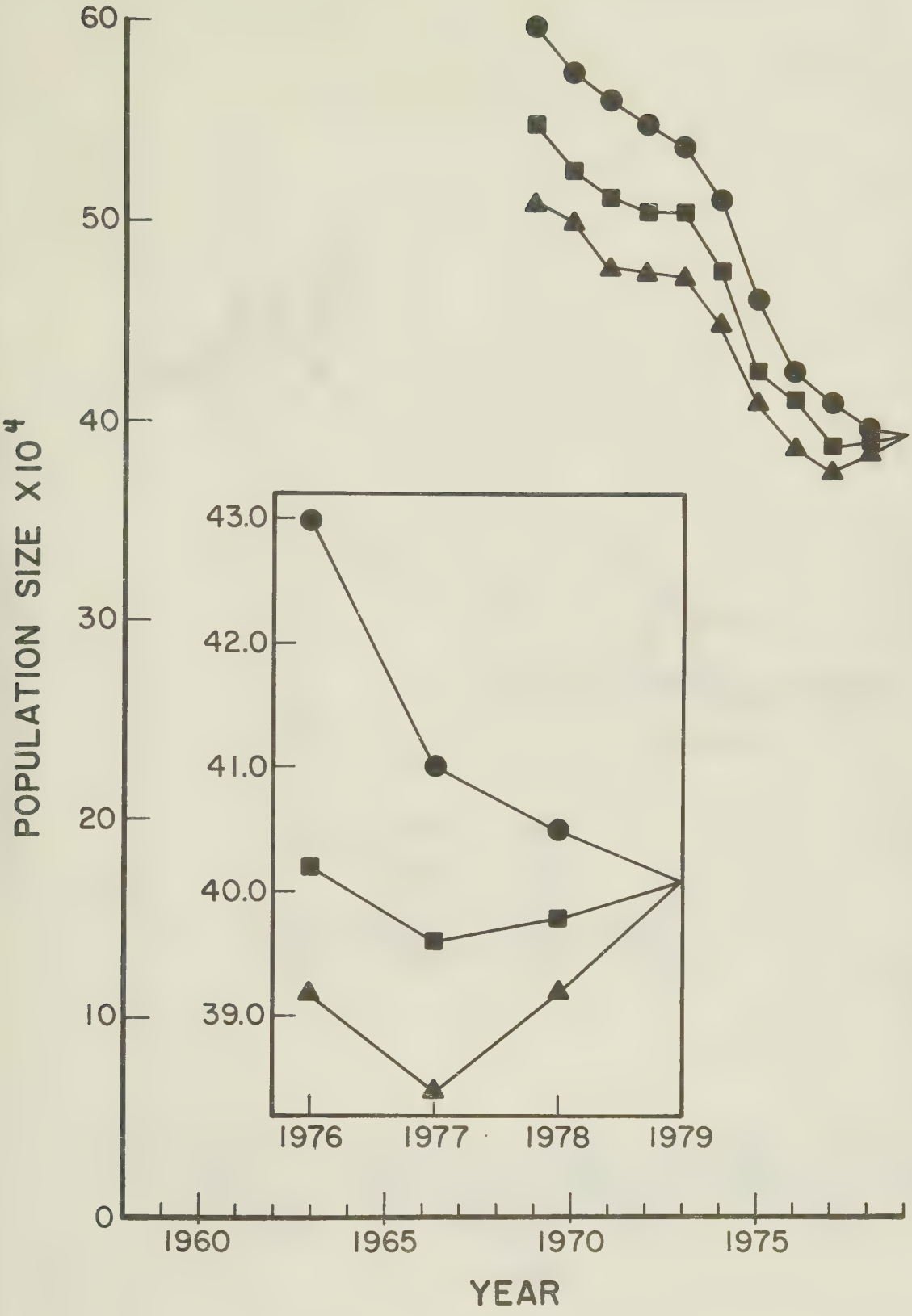


Figure 12. Northern whitebelly spinner dolphin.

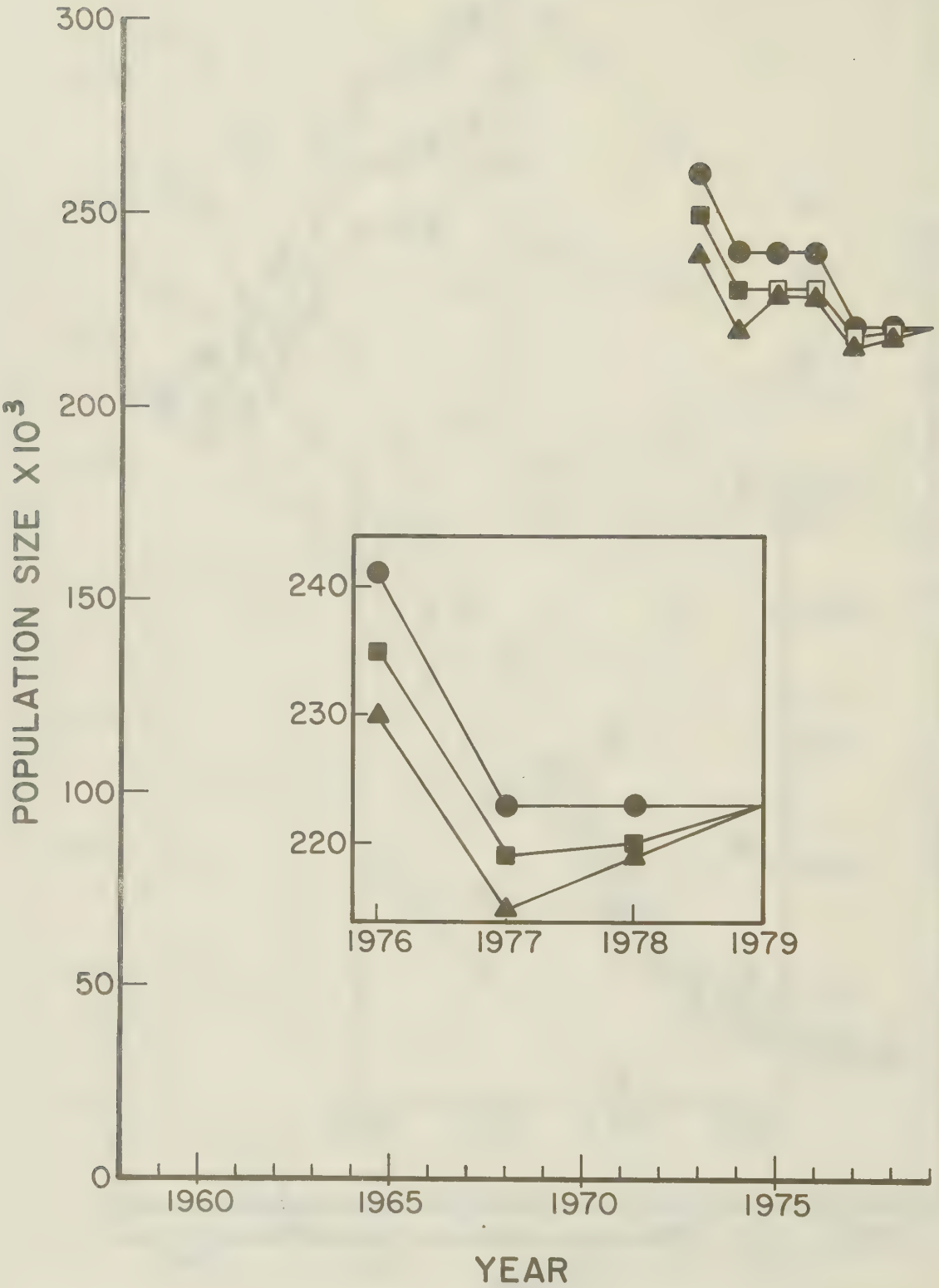


Figure 13. Southern whitebelly spinner dolphin.

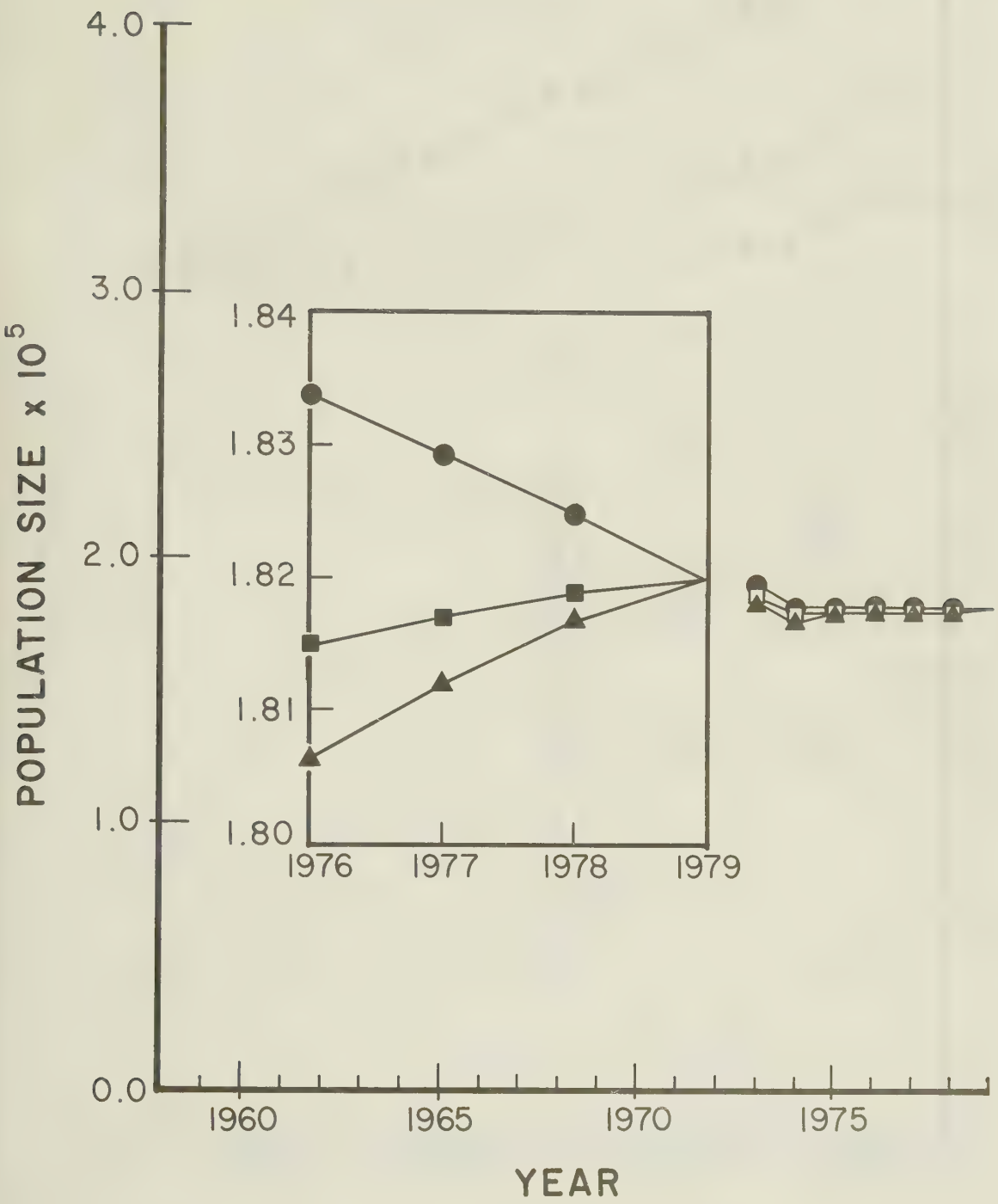


Figure 14. Northern tropical common dolphin.

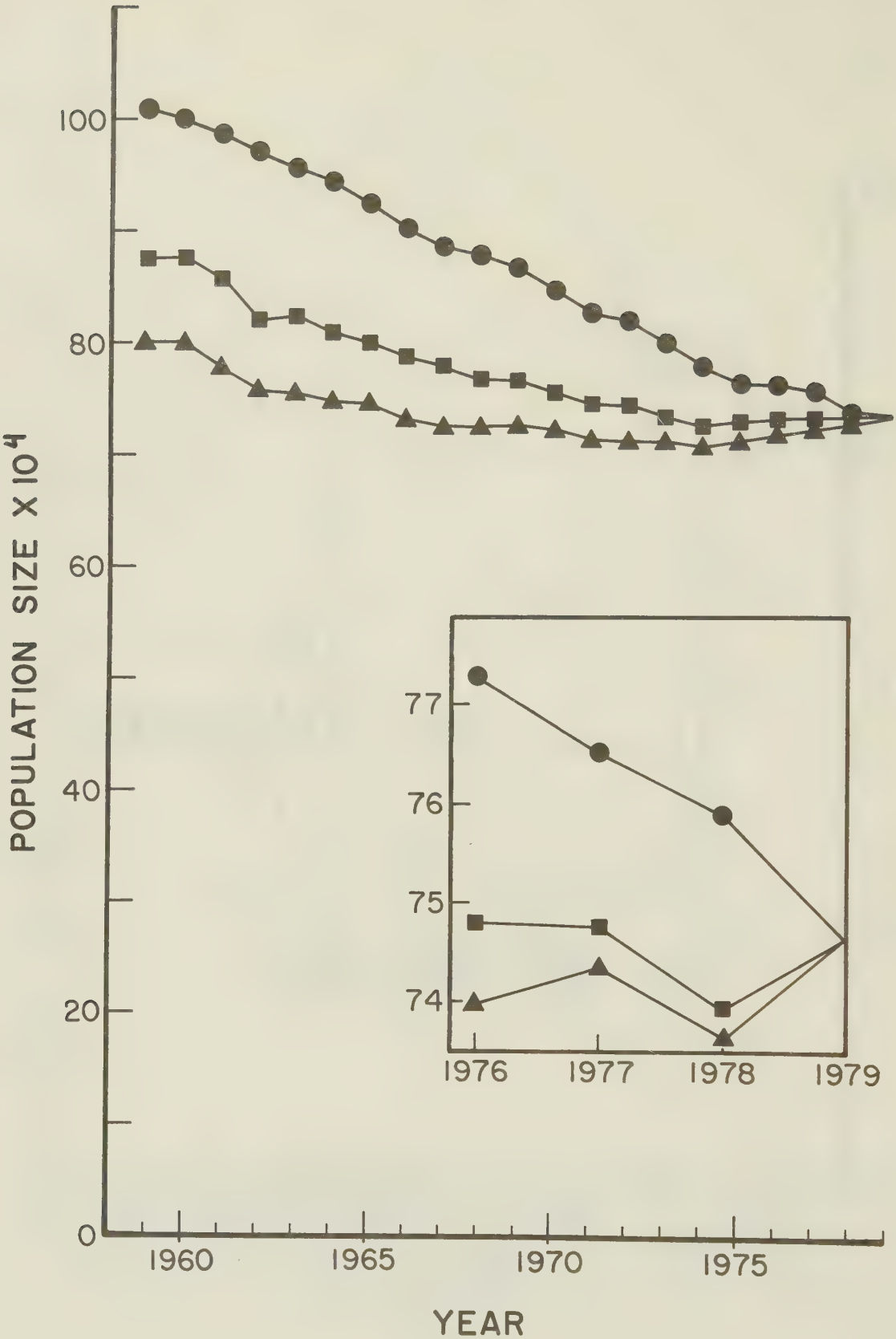


Figure 15. Central tropical common dolphin.

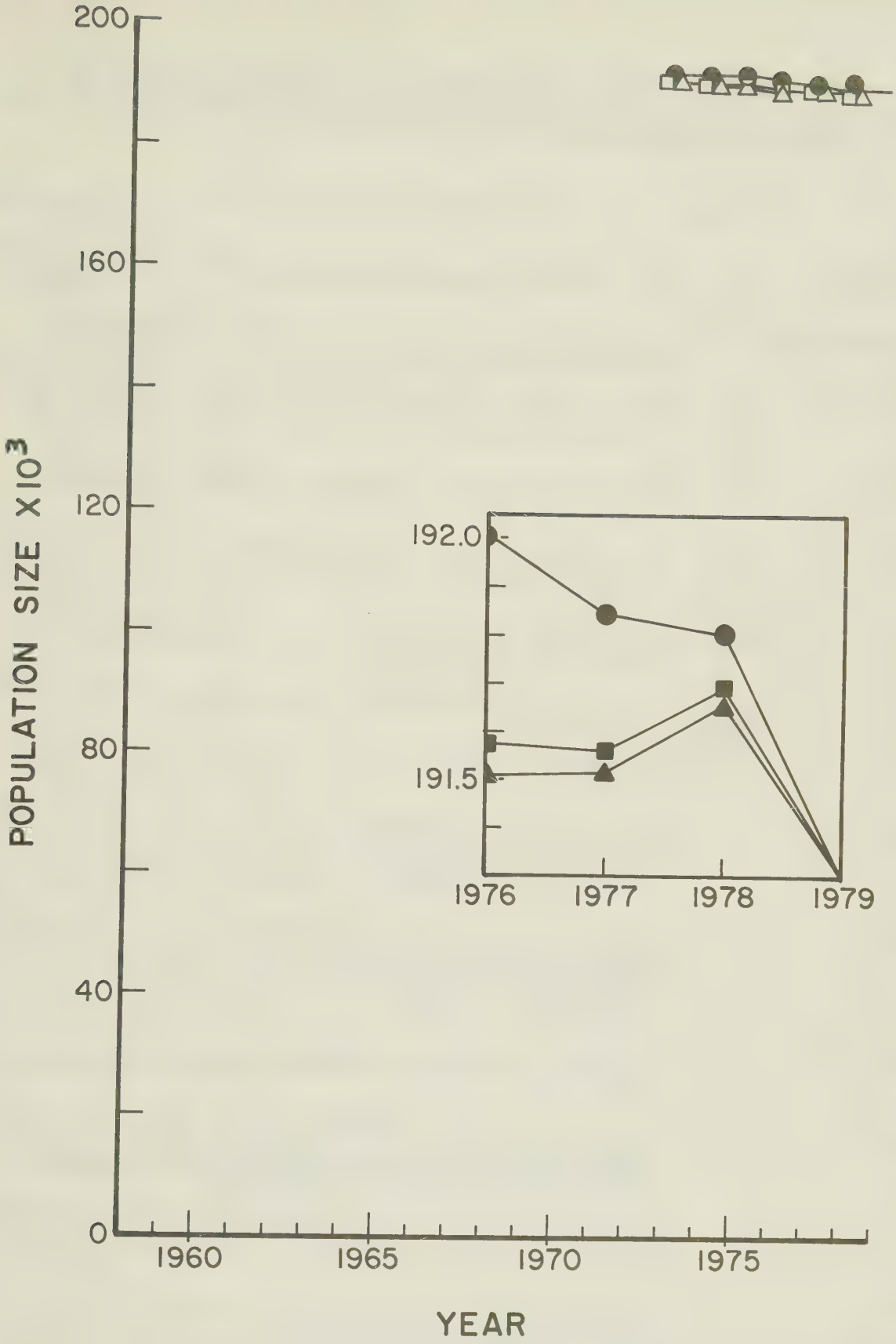


Figure 16. Central tropical striped dolphin.

Table 1. Management, scientific, and legal actions and events concerning the incidental kill of porpoise in the eastern tropical Pacific tuna purse seine fishery.

Date	Management and Legal Actions
October 1972	Marine Mammal Protection Act enacted by U.S. Congress.
Oct 1972-Oct 1974	Under the MMPA, fishery temporarily exempted from moratorium provisions of the Act for a two-year period.
Sep 1974	NMFS proposes to issue 1974-75 general permit to the tuna fishery; action involved in litigation.
Sep 1975	NMFS proposes 1976 regulations; action involved in litigation.
May 1976	U.S. District Court Judge Richey rules against NMFS's 1975 and 1976 permit actions.
Jun 1976	NMFS amends 1976 regulations to limit kill to 78,000 animals for 1976 fishing season.
Jul 1976	First Status of Porpoise Stocks Workshop
Aug 1976	U.S. Court of Appeals sustains Judge Richey's ruling but grants a Stay of the order until January 1977.
Oct 1976	NMFS announces prohibition on encircling porpoises to limit kill to quota of 78,000 animals. Temporary restraining order delays prohibition until November 1976.
Oct 1976	NMFS issues 1977 proposed permit with total of quotas on killing of 62,420 animals, and prohibition on intentional take of eastern spinner dolphin; action involved in litigation.
Jun 1977	1977 NMFS regulations upheld by Judge Richey and placed into effect.
Jul 1977	NMFS issues proposed regulations for 1978, 1979, and 1980. Totals of proposed quotas: 51,945 for 1978, 41,610 for 1979 and 31,150 for 1980.
Jan 1978	Total of quotas of 51,945 and no intentional take of eastern spinners in effect.
Jan 1979	Total of quotas of 41,610 and no intentional take of eastern spinners in effect.
Aug 1979	Second Status of Porpoise Stocks Workshop

Table 2. List of major stocks, with area inhabited in nm^2, and minor stocks of porpoise involved in the eastern tropical Pacific purse seine fishery

Species/Stock	Area (nm^2)
Spotted dolphin (*Stenella attenuata*)	
coastal	199,817
northern offshore*	3,605,244
southern offshore*	924,416
Spinner dolphin (*Stenella longirostris*)	
eastern	2,173,910
Costa Rican	38,614
northern whitebelly	2,921,099
southern whitebelly	1,136,635
Common dolphin (*Delphinus delphis*)	
Baja neritic	90,504
northern tropical	550,457
central tropical	2,151,375
southern tropical	822,010
Striped dolphin (*Stenella coeruleoalba*)	
northern tropical	528,252
central tropical	2,177,430
southern tropical	1,912,702
Rough-toothed dolphin (*Steno bredanensis*)	
Bottlenose dolphin (*Tursiops truncatus*)	
Risso's dolphin (*Grampus griseus*)	
Pacific white-sided dolphin (*Lagenorhynchus obliquidens*)	
Fraser's dolphin (*Lagenodelphis hosei*)	
Melon-headed whale (*Peponocephala electra*)	
Pygmy killer whale (*Feresa attenuata*)	
Short-finned pilot whale (*Globicephala macrorhynchus*)	
False killer whale (*Pseudorca crassidens*)	

* The offshore spotted dolphin is considered alternately as two stocks and as one stock; in the latter case the area inhabited is the sum of the two indicated areas.

Table 3. Sampling intensity from the research vessels in areas near the equator to determine the magnitude of possible biases in population estimates due to possibly non-uniform density of porpoise. Area is in units of number of 1^{o} squares in region.

Region	Area	Days searching	Days/ unit area
Northern Outside (excluding 1°S-3°N)	532	17	0.032
Southern Outside (excluding 1°-3°S)	130	3	0.023
Combined Outside	662	20	0.030
Equatorial 0°-3°N	99	6.5*	0.066
Equatorial 0°-3°S	76	6.5*	0.086
Combined Equatorial	175	13	0.074

* Assumes effort in the equatorial region was equally distributed on both sides of the equator.

Table 4. Mean perpendicular sighting distance (P) and Beaufort number*(B) for each research vessel sighting, by ship, species composition, area and sighting cue. Sample sizes in parentheses.

Ship	Species	Area		Sighting Cue: Birds		Sighting Cue: Not Birds	
Jordan	All	Inside	P	1.6	(38)	0.8	(97)
			B	1.9	(38)	1.8	(97)
		Outside	P	0.5	(3)	0.8	(83)
			B	2.0	(3)	2.0	(83)
	Spotted and Spinner	Inside	P	1.7	(26)	0.4	(12)
			B	2.0	(26)	2.1	(12)
		Outside	P	0.8	(2)	0.9	(12)
			B	2.0	(2)	1.8	(12)
Cromwell	All	Inside	P	1.5	(41)	0.9	(26)
			B	2.5	(41)	2.5	(26)
		Outside	P	1.0	(3)	0.4	(4)
			B	2.3	(3)	2.5	(4)
	Spotted and Spinner	Inside	P	1.4	(35)	0.5	(5)
			B	2.4	(35)	2.2	(5)
		Outside	P	0.8	(1)	0.5	(1)
			B	3.0	(1)	3.0	(1)

* Note that these are Beaufort numbers at the time of sighting, not during the sighting effort.

Table 5. Mean school size (S_i), proportion of total sightings for the target species $\left(\frac{n_{iA}}{n_A}\right)$ from the 1979 aerial survey data, and the ratio of density estimates for each species to the overall density estimate from the tuna vessel sighting data $\left(\frac{D_{iT}}{D_T}\right)$ by species.

Species	S_i	$\frac{n_{iA}}{n_A}$	$\frac{D_{iT}}{D_T}$
spotted	316.4	0.2500	.3591
spinner	648.7	0.1071	.1937
common	236.5	0.5357	.3176
striped	102.3	0.0893	.1194
Fraser's	60.0	0.0179	.0099

Table 6. Estimates of the proportions (P'_{ik}) of each of the target species in the three statistical areas, adjusted for differences in detectability.

Species	Inshore Area (aircraft area)	Offshore Area north of equator	Offshore Area south of equator
Spotted dolphin	.472	.375	.308
Spinner dolphin	.124	.099	.109
Common dolphin	.367	.455	.436
Striped dolphin	.020	.052	.122

Table 7. Estimates of 1979 population sizes by stock for target species in thousands of animals. Estimated standard deviations for the unadjusted estimates shown in parentheses.

Species	Stock	Unadjusted	Adjusted
Spotted	Coastal	183.1 (38.8)	169.1
	N. Offshore	2,761.0 (786.8)	2,329.0
	S. Offshore	557.0 (150.6)	559.7
	Offshore Combined	3,318.0 (935.2)	2,88.7
Spinner	Costa Rican	9.1 (2.0)	9.7
	Eastern	305.4 (68.2)	298.4
	N. Whitebelly	401.3 (147.5)	324.8
	S. Whitebelly	223.2 (72.9)	204.3
Common	N. Tropical	182.0 (59.6)	426.6
	Central Tropical	746.0 (195.1)	1,653.4
	S. Tropical	412.1 (118.6)	996.3
Striped	N. Tropical	44.9 (11.4)	33.4
	Central Tropical	191.3 (46.3)	133.1
	S. Tropical	388.0 (156.9)	190.8
Fraser's		29.3 (14.6)	34.3

Table 8. Minimal population size estimates for non-target species from the 1979 aerial survey data in thousands and estimates of relative density of schools from tuna vessel observer data. 1977-1979 mean school density per 1000 nm^2.

Species	Aerial survey large schools	Relative school density from tuna boats
Rough-toothed dolphin	5.0	-
Bottlenose dolphin	40.2	0.674
Risso's dolphin	243.2	0.125
Pilot whales	0.9	0.437

Table 9. Estimated numbers of porpoise killed directly by all fleets in the years 1959 to 1972, by stock, and in total.

Species	Stock	Year													
		59	60	61	62	63	64	65	66	67	68	69	70	71	72
Spotted	N. Off-shore	78236	388538	436078	179607	193727	315304	342238	307295	204978	177846	362885	351970	174716	282610
Spinner	Eastern	29283	145424	163218	67224	72509	118014	128095	115016	76720	66565	120789	117156	58156	94069
Spinner	N. White-belly	0	0	0	0	0	0	0	0	0	0	15034	14582	7238	11708
Common	Central Tropical	4247	21092	23673	9750	10517	17117	18579	16682	11127	9655	19699	19107	9485	15342
TOTAL		111766	555054	622969	256581	276753	450434	488912	438993	292825	254066	518407	502815	249595	403729

Table 10. Estimated numbers of porpoise killed directly by the U.S. fleet in the years 1973 to 1978, by stock, with estimated standard deviations given in parentheses.

Species	Stock	Year 73	74	75	76	77	78
Spotted							
	Coastal	2618 (2098)	15 (18)	0 (0)	0 (0)	63 (44)	0 (0)
	N.Offshore	95401 (16849)	74575 (23760)	82071 (14362)	38494 (7716)	11877 (1667)	12081 (2261)
	S. Offshore	16068 (7921)	0 (0)	1788 (1264)	18691 (5719)	272 (115)	724 (436)
Spinner							
	Eastern	20838 (7017)	17829 (2388)	38945 (23068)	6913 (3526)	1973 (482)	881 (228)
	N.Whitebelly	29026 (14004)	43924 (33900)	28994 (17809)	16711 (2730)	2723 (339)	3363 (1268)
	S. Whitebelly	15013 (7032)	0 (0)	1783 (1445)	14984 (4824)	335 (249)	107 (77)
Common							
	Baja Neritic & N.Tropical	4566 (485)	0 (0)	7 (5)	322 (258)	150 (69)	182 (140)
	Central Trop.	12987 (1438)	3318 (705)	2291 (878)	5062 (320)	6441 (2253)	858 (518)
Striped							
	N. Tropical	0 (0)	26 (27)	99 (35)	99 (86)	7 (7)	0 (0)
	Central Trop.	40 (43)	115 (94)	817 (345)	114 (103)	12 (9)	232 (98)
	S. Tropical	0 (0)	0 (0)	0 (0)	2028 (203)	83 (71)	14 (15)
Bottlenose		0 (0)	72 (27)	154 (63)	20 (4)	18 (7)	54 (36)
Fraser's		0 (0)	0 (0)	3 (3)	633 (639)	61 (56)	0 (0)
Rough-toothed		0 (0)	7 (5)	0 (0)	0 (0)	0 (0)	0 (0)
Risso's		0 (0)	0 (0)	0 (0)	37 (40)	0 (0)	0 (0)
Total		196556 (33493)	139882 (57070)	156955 (26960)	104218 (13439)	24045 (3490)	18525 (3697)

Table 11. Estimates of kill-per-set for the non-U.S. fleet by year, for successful and unsuccessful sets, obtained by interpolation from U.S. rates, 1973 to 1979, with estimated standard deviations shown in parentheses.

	Year							
Set Type	71-72	73	74	75	76	77	78	79
Successful sets	56.12	44.95	33.78	22.61	17.55	12.49	7.44	2.38*
	(8.59)	(5.82)	(3.59)	(3.25)	(2.44)	(1.66)	(0.94)	(0.97)
Unsuccessful sets	11.67	7.99	4.31	0.62	0.65	0.68	0.71	0.74
	(4.57)	(3.04)	(1.53)	(0.17)	(0.16)	(0.21)	(0.29)	(0.39)

* Kill rate for U.S. vessels observed in first half of 1979 by NMFS.

Table 12. Estimated numbers of porpoise killed directly by non-U.S. fleet, by stock and in total, from 1973 to 1978, with estimated standard deviations for the totals shown in parentheses.

Species	Stock	Year 73	74	75	76	77	78
Spotted	Coastal	1602	8	0	0	98	0
	N.Offshore	29588	16082	15641	6590	9310	6395
	S.Offshore	787	0	523	3842	90	282
Spinner	Eastern	9731	6899	4350	1155	2768	1223
	N.Whitebelly	2408	1378	4242	2696	1517	621
	S.Whitebelly	735	0	520	2417	120	32
Common	Baja Neritic & N.Tropical	2794	0	2	110	235	314
	C.Tropical	7956	1423	669	1729	10600	1507
	S.Tropical	0	0	0	37	9	45
Striped	N.Tropical	0	10	28	34	11	0
	C.Tropical	25	48	239	40	20	285
	S.Tropical	0	0	0	202	20	1
Bottlenose		0	31	44	6	29	95
Fraser's		0	0	1	38	15	0
Rough-toothed		0	2	0	0	0	0
Risso's		0	0	0	0	2	0
Total		55626	25881+	26262+	18897	24846*	10800
		(6064)	(2587)	(3664)	(2180)	(2909)	(1238)

\+ Totals slightly different than sums due to rounding errors.

* Includes 4 animals in other stocks.

Table 13. Estimated numbers of porpoise seriously injured by the U.S. fleet, by stock, for the years 1975 to 1978. The estimated numbers seriously injured in other stocks are almost all zero or very small, and are not shown. Standard deviations are shown in parentheses.

Species	Stock	75	76	77	78
Spotted					
	Coastal	0 (0)	0 (0)	0 (0)	0 (0)
	N.Offshore	6616 (727)	2106 (470)	766 (150)	503 (85)
	S.Offshore	24 (26)	266 (104)	11 (7)	20 (15)
Spinner					
	Eastern	1832 (725)	577 (273)	123 (57)	87 (41)
	N.Whitebelly	949 (583)	949 (329)	217 (36)	191 (59)
	S. Whitebelly	9 (9)	326 (160)	6 (4)	5 (3)
Common					
	Baja neritic & N.Tropical	0 (0)	23 (4)	39 (20)	5 (3)
	C.Tropical	163 (87)	243 (29)	249 (203)	34 (31)
Total		9690 (825)	4522 (839)	1407 (383)	841 (124)

Table 14. Numbers seriously injured as a percent of numbers killed directly by the U.S. fleet, for spotted, spinner and common dolphin, for the years 1975 to 1978.

Species	Year 75	76	77	78	75-78	
Spotted	7.9	4.1	6.4	4.1	6.2	5.5
Spinner	4.0	4.8	6.4	6.5	4.5	
Common	1.7	1.9	1.7	1.2	1.7	

Table 15. Estimated total porpoise killed, including seriously injured, by stock, for U.S and non-U.S. fleets from 1959 to 1978. Totals given reflect only stocks listed in this table. Also shown are total estimated kills used in 1976 (SOPS/79/1, p. 6-8).

Species - Stock	Year																			
	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78
Spotted																				
Coastal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4452	24	0	0	167	0
N. Offshore	82539	409908	460063	189485	204382	332646	361061	324197	216252	187628	382843	371328	184326	298154	131863	95643	105564	47460	22549	19241
S. Offshore	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17782	0	2376	22957	379	1038
Spinner																				
Eastern	30657	152251	170880	70380	75913	123554	134108	120416	30322	69690	125791	122008	60564	97965	32250	26088	45301	8700	5041	2270
N. Whitebelly	0	0	0	0	0	0	0	0	0	0	16408	15914	7900	12778	33163	47794	34355	20485	4554	4215
S. Whitebelly	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16614	0	2333	17843	489	146
Common																				
N. Tropical	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7485	0	9	457	428	505
C. Tropical	4092	20322	22808	9394	10132	16491	17900	16072	10721	9302	18980	18409	9138	14781	21299	4822	3134	7067	17470	2417
Striped																				
N. Tropical	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	36	127	133	18	0
C. Tropical	0	0	0	0	0	0	0	0	0	0	0	0	0	0	65	163	1056	154	32	517
S. Tropical	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2230	103	15
Bottlenose	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	103	198	26	47	149
Fraser's	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	671	76	0
Rough-Toothed	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0
Risso's	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	39	0	0
Total	117288	582481	653751	269259	290427	472691	513069	460685	307295	266620	544022	527659	261928	423678	264973	174682	194457	128222	51353	30513
Total SOPS/79/1	206000	853000	713000	169000	213000	407000	475000	449000	311000	262000	529000	492000	319000	348000	217000	120000	181000	-	-	-

Table 16. Estimates of annual pregnancy rates for northern offshore spotted and eastern spinner porpoise for 1973 to 1978, by two methods.

Year	Northern Offshore Spotted		Eastern Spinner	
	Method 1	Method 2	Method 1	Method 2
1973	0.54	0.40	0.23	0.43
1974	0.34	0.35	0.40	0.47
1975	0.31	0.25	0.37	0.46
1976	0.32	0.34	0.28	0.35
1977	0.24	0.39	0.29	0.44
1978	0.23	0.18	0.60	0.48
73-78	0.38	0.32	0.34	0.45

Table 17. Estimates of gross reproductive rates (G), with 95% confidence intervals (CI) and percentages female, mature, and the annual pregnancy rate (P) under two methods, for the years indicated. Estimates are given only for stocks where sample size was greater than 100 individuals.

Stock	% Female	% Mature	Method 1 G	Method 1 CI	Method 1 P	Method 2 G	Method 2 CI	Method 2 P
N.Offshore* (73-78)	56	56	11.7	10.1-13.3	38	10.1	8.7-11.5	32
S.Offshore*+	58	65	19.5	14.7-24.3	52	9.1	6.2-13.4	26
Spinner:								
Eastern (73-78)	51	43	7.5	6.5-8.5	34	9.8	8.6-11.0	45
N.Whitebelly (73-78)	51	52	9.4	8.0-10.8	36	8.8	7.4-10.2	36
S.Whitebelly (75-76)	52	63	9.7	6.9-12.5	30	6.7	4.3-9.1	21
Common:								
N.Tropical	51	60	10.9	0-24.5	35			
E.C.Tropical	49	48	9.2	7.6-10.8	39			
All Stocks	49	50	9.6	8.0-11.2	39			
Striped:								
All Stocks	48	46	10.9	5.9-15.9	50			

* Only net sets with kill ≥ 40 included.

\+ Possible seasonal bias in data.

Table 18. Estimates of the standard deviations of the estimates of total kill of porpoise, by stock, for the years 1973 to 1978, computed as outlined in Section 3.6. These estimates are underestimates for the several reasons described there, and are used only to obtain lower bounds for the variability of the quantities given in Table 20.

Species	Stock	Year 1973	1974	1975	1976	1977	1978
Spotted	Coastal	3568	29	0	0	117	0
	Northern offshore	23289	30472	18473	9513	3165	3601
	Southern offshore	8766	0	1678	7024	160	625
Spinner	Eastern	10860	3494	26833	4437	1232	587
	Northern Whitebelly	16000	36887	21102	3347	567	1589
	Southern Whitebelly	7782	0	1891	5744	363	105
Common	Baja Neritic	795	0	6	366	197	388
	Northern Tropical						
	Central Tropical	2358	1024	1201	447	6111	1459
Striped	Northern Tropical	0	37	45	115	18	0
	Central Tropical	70	133	446	139	24	218
	Southern Tropical	0	0	0	223	88	16
Bottlenose		0	39	81	5	18	99
Frasers		0	0	4	677	70	0
Rough toothed		0	6	0	0	0	0
Risso's		0	0	0	42	0	0
Total		45151	71268	33402	16534	7454	6089

Figure 19a. For northern offshore spotted dolphin, estimates of the variances and covariances of the estimated total kill by all fleets from 1959 to 1977 (Table 15). These are used as minimal estimates of the variances and covariances of the total kill during these years (Section 3.4.7) in the calculations of the variability of the quantities given in Table 20 ($X10^9$).

Year →	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972
1959	0.74	3.46	3.55	1.31	1.23	1.57	1.57	1.24	0.81	0.66	1.28	1.18	0.50	0.54
1960		16.32	16.80	6.25	5.90	7.71	7.62	5.95	3.98	3.17	6.14	5.68	2.37	2.61
1961			17.44	6.54	6.26	8.41	8.21	6.31	4.12	3.37	6.52	6.01	2.50	2.80
1962				2.49	2.43	3.38	3.25	2.45	1.60	1.31	2.53	2.32	0.95	1.09
1963					2.44	5.57	3.36	2.46	1.61	1.33	2.54	2.32	0.94	1.11
1964						5.64	5.17	3.59	2.37	1.96	3.73	3.39	1.34	1.67
1965							5.25	4.26	2.68	2.09	3.95	3.58	1.40	1.77
1966								4.13	2.47	1.79	3.39	3.06	1.18	1.53
1967									1.60	1.29	2.45	2.22	0.87	1.01
1968										1.15	2.21	2.03	3.17	0.90
1969											4.34	4.07	6.14	2.01
1970												3.87	5.68	2.01
1971													0.96	1.24
1972														2.08

Table 19b. For eastern spinner dolphin, estimates of the variances and covariances of the estimated total kill by all fleets from 1959 to 1977 (Table 15). These are used as minimal estimates of the variances and covariances of the total kill during these years (Section 3.4.7) in the calculations of the variability of the quantities given in Table 20 ($X10^8$).

Year →	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972
1959	1.12	5.29	5.46	2.04	1.93	2.54	2.56	2.06	1.35	1.11	2.17	2.03	8.78	1.05
1960		25.03	2.60	9.74	9.31	12.50	12.50	9.96	6.53	5.38	10.50	9.81	4.23	5.13
1961			27.13	1.03	9.95	13.70	13.60	1.07	6.99	5.78	11.30	10.50	4.53	5.57
1962				3.94	3.89	5.51	5.40	4.18	2.74	2.28	4.42	4.10	1.76	2.21
1963					3.94	5.84	5.62	4.25	2.80	2.33	4.51	4.17	1.77	2.29
1964						9.27	8.72	6.34	4.20	3.51	6.77	6.24	2.62	3.52
1965							8.95	7.39	4.70	3.74	7.21	6.64	2.76	3.76
1966								7.08	4.31	3.25	6.25	5.74	2.37	3.30
1967									2.81	2.30	4.43	4.08	1.69	2.19
1968										2.04	3.97	3.69	1.57	1.92
1969											7.86	7.41	3.33	4.18
1970												7.09	3.32	4.27
1971													1.76	2.40
1972														3.98

Table 19c. For northern whitebelly spinner dolphin, estimates of the variances and covariances of the estimated total kill by all fleets from 1959 to 1977 (Table 15). These are used as minimal estimates of the variances and covariances of the total kill during these years (Section 3.4.7) in the calculations of the variability of the quantities given in Table 20 ($X10^7$).

Year → / ↓	1969	1970	1971	1972
1969	2.17	1.33	2.61	2.66
1970		0.86	1.71	1.75
1971			3.49	3.61
1972				3.76

Table 19d. For central tropical common dolphin, estimates of the variances and covariances of the estimated total kill by all fleets from 1959 to 1977 (Table 15). These are used as minimal estimates of the variances and covariances of the total kill during these years (Section 3.4.7) in the calculations of the variability of the quantities given in Table 20 ($X10^7$).

Year → / ↓	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972
1959	0.38	1.84	1.97	0.77	0.77	1.13	1.18	1.01	0.67	0.57	1.14	1.09	0.51	0.75
1960		8.89	9.52	3.72	3.76	5.56	5.82	4.95	3.28	2.79	5.59	5.34	2.52	3.71
1961			10.27	4.04	4.12	6.17	6.43	5.45	3.61	3.07	6.16	5.88	2.78	4.12
1962				1.60	1.65	2.52	2.61	2.20	1.46	1.24	2.49	2.38	1.12	1.68
1963					1.73	2.69	2.77	2.32	1.54	1.31	2.63	2.51	1.18	1.79
1964						4.33	4.42	3.65	2.43	2.08	4.16	3.97	1.87	2.87
1965							4.69	4.07	2.67	2.24	4.49	4.28	2.01	3.11
1966								3.75	2.41	1.99	3.98	3.80	1.78	2.77
1967									1.60	1.36	2.71	2.59	1.21	1.85
1968										1.19	2.38	2.27	1.07	1.61
1969											4.81	4.62	2.22	3.33
1970												4.46	2.17	3.28
1971													1.10	1.69
1972														2.75

Table 20. For each stock, estimated pre-exploitation stock size ($\hat{N}_p$), ratio of present stock size to this level ($\hat{N}_{79}/\hat{N}_p$), and replacement yields ($\hat{RY}$), for present abundance estimates ($\hat{N}_{79}$) by two methods, for values of maximum net reproductive rate ($\hat{R}_{max}$) of 0, 2, and 4 percent, and for levels of population size (relative to $\hat{N}_p$) at which maximum net productivity of the population is obtained (MNPL) of 65, 72.5, and 80 percent. The population size estimates are obtained either accounting for suggested adjustments to the species proportions (adjusted), or not (unadjusted). The asterisk (*) indicates that a MNP level is not defined when $\hat{R}_m = 0$. Estimates of the standard deviations of the ratio of $\hat{N}_{79}/\hat{N}_p$ and of $\hat{N}_p$ are shown in parentheses for the unadjusted population size estimates.

Table 20a. Coastal Spotted

		Current Population Size ($\hat{N}_{79}$)					
		Unadjusted 1.831×10^5			Adjusted 1.691×10^5		
R_{max}	MNPL	$\hat{N}_p$ ($\times 10^5$)	$\hat{N}_{79}/\hat{N}_p$	$\hat{RY}$	$\hat{N}_p$ ($\times 10^5$)	$\hat{N}_{79}/\hat{N}_p$	$\hat{RY}$
0	*	1.877 (0.390)	0.98 (0.019)	0	1.737	0.97	0
0.02	0.65	1.864 (0.389)	0.98 (0.014)	224	1.724	0.98	223
0.02	0.725	1.857 (0.388)	0.99 (0.011)	299	1.717	0.98	299
0.02	0.80	1.846 (0.388)	0.99 (0.007)	334	1.707	0.99	336
0.04	0.65	1.854 (0.388)	0.99 (0.010)	316	1.714	0.99	316
0.04	0.725	1.845 (0.388)	0.99 (0.006)	319	1.705	0.99	320
0.04	0.80	1.835 (0.388)	1.00 (0.002)	165	1.695	1.00	167

Table 20b. Northern Offshore Spotted

		Current Population Size ($\hat{N}_{79}$)					
		Unadjusted			Adjusted		
		27.610×10^5			23.290×10^5		
R_{max}	MNPL	$\hat{N}_p$ ($\times 10^5$)	$\hat{N}_{79}/\hat{N}_p$	$\hat{RY}$	$\hat{N}_p$ ($\times 10^5$)	$\hat{N}_{79}/\hat{N}_p$	$\hat{RY}$
0	*	71.881 (11.580)	0.38 (0.080)	0	67.561	0.34	0
0.02	0.65	62.349 (9.538)	0.44 (0.094)	52029	58.820	0.40	44761
0.02	0.725	60.767 (9.294)	0.45 (0.099)	54734	57.442	0.41	46373
0.02	0.80	59.478 (9.141)	0.46 (0.103)	55212	56.319	0.41	46578
0.04	0.65	54.703 (8.278)	0.50 (0.110)	100352	51.772	0.45	87472
0.04	0.725	52.116 (7.907)	0.53 (0.121)	107998	49.521	0.47	92152
0.04	0.80	50.057 (7.710)	0.55 (0.131)	110322	47.729	0.49	93136

Table 20c. Southern Offshore Spotted

		Current Population Size ($\hat{N}_{79}$)					
		Unadjusted			Adjusted		
		5.570×10^5			5.597×10^5		
R_{max}	MNPL	$\hat{N}_p$ ($\times 10^5$)	$\hat{N}_{79}/\hat{N}_p$	$\hat{RY}$	$\hat{N}_p$ ($\times 10^5$)	$\hat{N}_{79}/\hat{N}_p$	$\hat{RY}$
0	*	6.015 (1.510)	0.93 (0.026)	0	6.042	0.93	0
0.02	0.65	5.935 (1.507)	0.94 (0.022)	2218	5.962	0.94	2219
0.02	0.725	5.891 (1.503)	0.95 (0.020)	3184	5.918	0.95	3187
0.02	0.80	5.822 (1.497)	0.96 (0.017)	4441	5.849	0.96	4444
0.04	0.65	5.867 (1.504)	0.95 (0.018)	3700	5.894	0.95	3701
0.04	0.725	5.797 (1.501)	0.96 (0.015)	4746	5.824	0.96	4747
0.04	0.80	5.699 (1.496)	0.98 (0.011)	5173	5.726	0.98	5170

Table 20d. Offshore Spotted Porpoise

		Current Population Size ($\hat{N}_{79}$)					
		Unadjusted			Adjusted		
		33.180×10^5			28.887×10^5		
R_{max}	MNPL	$\hat{N}_p$ ($\times 10^5$)	$\hat{N}_{79}/\hat{N}_p$	$\hat{RY}$	$\hat{N}_p$ ($\times 10^5$)	$\hat{N}_{79}/\hat{N}_p$	$\hat{RY}$
0	*	77.897 (12.251)	0.43 (0.081)	0	73.604	0.39	0
0.02	0.65	67.363 (10.431)	0.49 (0.096)	60795	63.791	0.45	54164
0.02	0.725	65.477 (10.090)	0.51 (0.101)	65236	62.127	0.47	57190
0.02	0.80	63.930 (9.855)	0.52 (0.107)	66325	60.767	0.48	57763
0.04	0.65	58.976 (9.035)	0.56 (0.110)	114992	55.931	0.52	104108
0.04	0.725	55.882 (8.488)	0.59 (0.123)	126905	53.207	0.54	112589
0.04	0.80	53.392 (8.152)	0.62 (0.136)	132161	51.032	0.57	115382

Table 20e. Eastern Spinner

		Current Population Size ($\hat{N}_{79}$)					
		Unadjusted			Adjusted		
		3.054×10^5			2.984×10^5		
R_{max}	MNPL	$\hat{N}_p$ ($\times 10^5$)	$\hat{N}_{79}/\hat{N}_p$	$\hat{RY}$	$\hat{N}_p$ ($\times 10^5$)	$\hat{N}_{79}/\hat{N}_p$	$\hat{RY}$
0	*	18.731 (3.264)	0.16 (0.041)	0	18.661	0.16	0
0.02	0.65	16.748 (2.991)	0.18 (0.048)	6092	16.694	0.18	5954
0.02	0.725	16.475 (2.969)	0.19 (0.049)	6108	16.424	0.18	5968
0.02	0.80	16.253 (2.956)	0.19 (0.050)	6108	16.203	0.18	5968
0.04	0.65	15.110 (2.764)	0.20 (0.054)	12171	15.068	0.20	11895
0.04	0.725	14.654 (2.726)	0.21 (0.056)	12215	14.615	0.20	11935
0.04	0.80	14.288 (2.708)	0.21 (0.059)	12216	14.252	0.21	11936

Table 20f. Northern Whitebelly Spinner

		Current Population Size ($\hat{N}_{79}$)					
		Unadjusted 4.013×10^5			Adjusted 3.248×10^5		
R_{max}	MNPL	$\hat{N}_p$ ($\times 10^5$)	$\hat{N}_{79}/\hat{N}_p$	$\hat{RY}$	$\hat{N}_p$ ($\times 10^5$)	$\hat{N}_{79}/\hat{N}_p$	$\hat{RY}$
0	*	5.971 (1.556)	0.67 (0.098)	0	5.197	0.62	0
0.02	0.65	5.644 (1.498)	0.71 (0.099)	5583	4.899	0.66	4954
0.02	0.725	5.535 (1.468)	0.73 (0.102)	6852	4.807	0.68	5878
0.02	0.80	5.412 (1.429)	0.74 (0.107)	7765	4.707	0.69	6405
0.04	0.65	5.361 (1.454)	0.75 (0.099)	10206	4.637	0.70	9256
0.04	0.725	5.172 (1.405)	0.78 (0.103)	12529	4.476	0.73	11096
0.04	0.80	4.962 (1.341)	0.81 (0.112)	14643	4.305	0.75	12483

Table 20g. Southern Whitebelly Spinner

		Current Population Size ($\hat{N}_{79}$)					
		Unadjusted 2.232×10^5			Adjusted 2.043×10^5		
R_{max}	MNPL	$\hat{N}_p$ ($\times 10^5$)	$\hat{N}_{79}/\hat{N}_p$	$\hat{RY}$	$\hat{N}_p$ ($\times 10^5$)	$\hat{N}_{79}/\hat{N}_p$	$\hat{RY}$
0	*	2.606 (0.736)	0.86 (0.052)	0	2.417	0.85	0
0.02	0.65	2.543 (0.730)	0.88 (0.046)	1635	2.355	0.87	1601
0.02	0.725	2.513 (0.725)	0.89 (0.045)	2272	2.326	0.88	2211
0.02	0.80	2.470 (0.715)	0.90 (0.044)	3073	2.286	0.89	2965
0.04	0.65	2.488 (0.725)	0.90 (0.041)	2820	2.301	0.89	2779
0.04	0.725	2.437 (0.719)	0.92 (0.038)	3657	2.252	0.91	3611
0.04	0.80	2.369 (0.708)	0.94 (0.034)	4418	2.186	0.93	4421

Table 20h. Baja Neritic and Northern Common

		Current Population Size ($\hat{N}_{79}$)					
		Unadjusted 1.820×10^5			Adjusted 4.266×10^5		
R_{max}	MNPL	$\hat{N}_p$ ($\times 10^5$)	$\hat{N}_{79}/\hat{N}_p$	$\hat{RY}$	$\hat{N}_p$ ($\times 10^5$)	$\hat{N}_{79}/\hat{N}_p$	$\hat{RY}$
0	*	1.909 (0.596)	0.95 (0.015)	0	4.355	0.98	0
0.02	0.65	1.887 (0.596)	0.96 (0.012)	431	4.332	0.98	445
0.02	0.725	1.875 (0.595)	0.97 (0.011)	597	4.319	0.99	613
0.02	0.80	1.857 (0.594)	0.98 (0.008)	756	4.300	0.99	740
0.04	0.65	1.870 (0.595)	0.97 (0.009)	654	4.314	0.99	660
0.04	0.725	1.853 (0.595)	0.98 (0.007)	747	4.297	0.99	732
0.04	0.80	1.835 (0.595)	0.99 (0.004)	636	4.279	1.00	588

Table 20i. Central Tropical Common

		Current Population Size ($\hat{N}_{79}$)					
		Unadjusted 7.460×10^5			Adjusted 16.534×10^5		
R_{max}	MNPL	$\hat{N}_p$ ($\times 10^5$)	$\hat{N}_{79}/\hat{N}_p$	$\hat{RY}$	$\hat{N}_p$ ($\times 10^5$)	$\hat{N}_{79}/\hat{N}_p$	$\hat{RY}$
0	*	10.118 (2.093)	0.74 (0.075)	0	19.192	0.86	0
0.02	0.65	9.095 (1.949)	0.82 (0.063)	7464	18.018	0.92	8590
0.02	0.725	8.754 (1.896)	0.85 (0.060)	9204	17.596	0.94	10311
0.02	0.80	8.348 (1.827)	0.89 (0.058)	10825	17.112	0.97	10801
0.04	0.65	8.451 (1.906)	0.88 (0.045)	10557	17.389	0.95	10696
0.04	0.725	8.054 (1.889)	0.93 (0.033)	10994	17.004	0.97	10231
0.04	0.80	7.711 (1.912)	0.97 (0.016)	9438	16.727	0.99	8247

Table 20j. Central Tropical Striped

		Current Population Size ($\hat{N}_{79}$)					
		Unadjusted 1.913×10^5			Adjusted 1.331×10^5		
R_{max}	MNPL	$\hat{N}_p$ ($\times 10^5$)	$\hat{N}_{79}/\hat{N}_p$	$\hat{RY}$	$\hat{N}_p$ ($\times 10^5$)	$\hat{N}_{79}/\hat{N}_p$	$\hat{RY}$
0	*	1.933 (0.463)	0.99 (0.004)	0	1.351	0.99	0
0.02	0.65	1.930 (0.463)	0.99 (0.003)	117	1.348	0.99	116
0.02	0.725	1.928 (0.463)	0.99 (0.003)	178	1.346	0.99	176
0.02	0.80	1.925 (0.463)	0.99 (0.002)	268	1.343	0.99	265
0.04	0.65	1.928 (0.463)	0.99 (0.003)	200	1.346	0.99	199
0.04	0.725	1.925 (0.463)	0.99 (0.002)	276	1.343	0.99	275
0.04	0.80	1.921 (0.463)	1.00 (0.002)	349	1.339	0.99	348

APPENDIX 1

WORKSHOP PARTICIPANTS

K. Radway Allen
Division of Fisheries and Oceanography
CSIRO
P.O. Box 21
Cronulla, NSW 2230 Australia

Dale McCullough
Dept. of Forestry & Resource Management
Univ. of Calif., Berkeley
145 Mulford Hall
Berkeley, CA 94720

Bradford Brown
National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole, MA 02543

Daniel Goodman
Scripps Institution of Oceanography
A-024
La Jolla, CA 92093

Charles Fowler
National Marine Mammal Laboratory
7600 Sandpoint Way, N.E.
Seattle, WA 98115

Robin Allen
IATTC
c/o Scripps Institution of Oceanography
La Jolla, CA 92093

Tim Smith
Gary Sakagawa
Rennie Holt
Nancy Lo
William Perrin
Warren Stuntz
David Au

National Marine Fisheries Service
Southwest Fisheries Center
P.O. Box 271
La Jolla, CA 92038

PARTICIPANTS, CONT.

D. G. Chapman
Dean, College of Fisheries
University of Washington
Seattle, WA 98195

Sidney Holt
Div. of Environmental Management, UNEP
FAO of the UN
Via delle Terme di Caracalla
Rome, Italy 00100

Toshio Kasuya
Ocean Research Institute
University of Tokyo
1-15-1 Minamidai, Nakano-ku
Tokyo, Japan

Joseph E. Powers
National Marine Fisheries Service
Southeast Fisheries Center
75 Virginia Beach Drive
Miami, FL 33149

National Marine Fisheries Service Staff

William Aron
Director, Office of Marine Mammals and Endangered Species
Page Bldg. 2, Room 412-C
3300 Whitehaven Street
Washington, DC 20235

IATTC Staff

Inter-American Tropical Tuna Commission
c/o Scripps Institution of Oceanography
La Jolla, CA 92037

Jeff Laake
Phillip Hammond

Southwest Fisheries Center Staff

Charles Oliver
Bruce Wahlen
Tom Polacheck
Jay Barlow
Frank Ralston
Ken Wallace
Eric Barham
Tod Foster
John Henderson

APPENDIX 2

AGENDA FOR SOPS WORKSHOP

ABREVIATED AGENDA

Status of Porpoise Stocks Workshop
August 27-31, 1979

Target Time Schedule		
M 0900 1100	I.	Introduction
	I.1	Welcome
	I.2	Brief History
	I.3	Terms of Reference & Charge
	I.4	Procedures
M 1100-1430	II.	Preliminary Discussion of Management Criteria (2 hour limited discussion)
	II.1	Introduction - Need for Criteria
	II.2	Marine Mammal Protection Act
	II.3	Measurement of the Criteria
M 1430-1500	III.	Estimation of Key Parameters
M 1500-1730	III.1	General Data Sources
M 1500-1730	III.2	Definition of Stocks
T 0830-1200	III.3	Incidental Kill Levels
T 1330-W 1200	III.4	Present Abundance
W 1330-1700	III.5	Reproduction and Mortality Rates
Th0830-1100	III.6	Pre-exploitation Abundance
W 1930-?	IV.	Final Discussion of Management Criteria
Th 1330-?	V.	Status of Stocks (Drafting of Reports)
	V.1	Spotted
	V.2	Spinner
	V.3	Common
	V.4	Striped
	V.5	Other
F 0900-1100	VI.	Research Recommendations
F 1330-?	VII.	Review of Draft Report

APPENDIX 3

DEFINITION OF OPTIMUM SUSTAINABLE POPULATION SIZE, FROM FEDERAL REGISTER 41:55536

Optimum sustainable population is a population size which falls within a range from the population level of a given species or stock which is the largest supportable within the ecosystem to the population level that results in maximum net productivity. Maximum net productivity is the greatest net annual increment in population numbers of biomass resulting from additions to the population due to reproduction and/or growth less losses due to natural mortality.

APPENDIX 4

LIST OF DOCUMENTS
STATUS OF PORPOISE STOCKS WORKSHOP

*SOPS/79/1 STAFF, PORPOISE/TUNA INTERACTION PROGRAM, OCEANIC FISH. RES. DIVISION. 1976. Report of the workshop on stock assessment of porpoises involved in the eastern Pacific yellowfin tuna fishery. (La Jolla, July 27-31, 1976). SWFC Admin. Rep. No. LJ-76-29.

SOPS/79/2 FOX, W. W., Jr. 1978. The tuna-dolphin programs: five years of progress. Oceans 11(3): 57-59. Also in NMFS Tuna Newsletter, No. 58, May-June 1978, 6 p.

*SOPS/79/3 PERRIN, W. F. 1975. Distribution and differentiation of populations of dolphins of the genus Stenella in the eastern tropical Pacific. Journal of the Fish. Res. Bd. Canada, 32(7): 1059-1067.

*SOPS/79/4 PERRIN, W. F., J. M. COE, AND J. R. ZWEIFEL. 1977. Growth and reproduction of the spotted porpoise, Stenella attenuata, in the offshore eastern tropical Pacific. Fish. Bull., U.S. 74(2): 229-269.

*SOPS/79/5 PERRIN, W. F., R. B. MILLER, AND P. A. SLOAN. 1977. Reproductive parameters of the offshore spotted dolphin, a geographical form of Stenella attenuata, in the eastern tropical Pacific, 1973-1975. Fish. Bull., U.S. 75(3): 629-633.

*SOPS/79/6 PERRIN, W. F., D. B. HOLTS, AND R. B. MILLER. 1977. Growth and reproduction of the eastern spinner dolphin, a geographical form of Stenella longirostris in the eastern tropical Pacific. Fish. Bull., U.S. 75(4): 725-750.

*SOPS/79/7 LO, N.C.H., J. E. POWERS, AND B. E. WAHLEN. 1978. Estimating and monitoring incidental marine mammal mortality in the eastern tropical Pacific purse seine fishery.

SOPS/79/8 KIMURA, M. AND W. F. PERRIN. 1976. Progress report on studies of the biology of the striped dolphin, Stenella coeruleoalba, in the eastern tropical Pacific. SWFC Admin. Rep. No. LJ-76-11, 51 p.

*SOPS/79/9 PERRIN, W. F., P. A. SLOAN, AND J. R. HENDERSON. 1979. Taxonomic status of the "southwestern" stocks of spinner dolphin, Stenella longirostris and spotted dolphin, S. attenuata. Rep. Int. Whal. Comm. 29: 175-184.

*SOPS/79/10 POWERS, J. E., N. C. H. LO, AND B. E. WAHLEN. 1979. A statistical analysis on effectiveness of porpoise rescue procedures in reducing incidental mortality. SWFC Admin. Rpt. LJ-79-7.

*SOPS/79/11 SMITH, T. D. AND T. POLACHECK. 1979. Uncertainty in estimating historical abundance of porpoise populations. U.S. Marine Mammal Commission, Washington, D.C. Report No. MMC-77/16.

SOPS/79/12 SMITH, T. D. AND T. POLACHECK. 1979. Analysis of a simple model for estimating historical population sizes. Fish. Bull. U.S. 76(4): 771-779.

SOPS/79/13 ZWEIFEL, J. AND W. F. PERRIN. MS. Fitting curves to odontocete length tooth layer data. Proc. Int. Conf. Age Determ. Odont. Cetaceans and Sirenians. Rep. Int. Whal. Comm. Spec. Issue.

*SOPS/79/14 AU, D. W. K. 1979. Porpoise distribution maps. SWFC internal memo.

*SOPS/79/15 FOWLER, C. W. 1979. Non-linearity in population dynamics with special reference to large mammals.

SOPS/79/16 PERRIN, W. F. AND J. E. POWERS. 1979. Role of a Nematode in natural mortality of the spotted dolphin.

SOPS/79/17 MAY, R. M., J. R. BEDDINGTON, COLIN W. CLARK, SIDNEY J. HOLT, AND RICHARD M. LAWS. 1979. Management of multispecies fisheries. Science 205: 267-277.

*SOPS/79/18 SMITH, T. AND T. POLACHECK. 1979. Estimating the size of porpoise populations in the eastern tropical Pacific prior to the beginning of incidental mortality by the tuna purse seine fleet.

*SOPS/79/19 LO, N. 1979. Estimated number of porpoises chased, encircled and captured associated with U.S. yellowfin tuna purse seine fishing in 1977.

SOPS/79/20 BREIWICK, J. M., E. D. MITCHELL, AND D. G. CHAPMAN. 1979. Initial population size of Bering Sea stock of bowhead whale, Balaena mysticetus: an iterative method, U.S. Marine Mammal Comm., Washington, D.C.

*SOPS/79/21 LO, N. 1979. Simulation results on the sampling distribution of the estimate of the number of porpoise killed by the yellowfin tuna purse seine fleet in 1977.

*SOPS/79/22 STUNTZ, W. E. 1979. Unobservable mortality of dolphins involved in the eastern tropical Pacific tuna fishery.

*SOPS/79/23 BARHAM, E. G. 1979. Aerial observations of Grampus griseus (Risso's dolphin): a possible index form for porpoise populations in the eastern tropical Pacific.

*SOPS/79/24 STUNTZ, W. E. and T. B. Shay. 1979. Report on Capture Stress Workshop, May 1979. SWFC Admin. Rept. No. LJ-79-28.

*SOPS/79/25 HAMMOND, P. S. and J. L. Laake. 1979. Estimates of the relative density of schools for nine species of marine mammals in the eastern tropical Pacific. Inter-American Tropical Tuna Commission internal report.

*SOPS/79/26 BARLOW, J. 1979. Reproductive seasonality in pelagic dolphins of the eastern tropical Pacific.

*SOPS/79/27 LO, N. AND T. SMITH. 1979. Estimation of incidental mortality of porpoise associated with the U.S. yellowfin tuna purse seine fishery from 1959-1972.

*SOPS/79/28 POWERS, J. E. 1979. A discussion of incidental mortality by unobserved United States purse seiners.

*SOPS/79/29 HOLT, R. S. and J. E. Powers. 1979. Abundance estimation of dolphin stocks involved in the eastern tropical Pacific yellowfin tuna fishery determined from aerial and ship surveys.

*SOPS/79/30 PERRIN, W. F. AND J. R. HENDERSON. 1979. Growth and reproductive rates in two populations of spinner dolphins, Stenella longirostris, with different histories of exploitation, SWFC Admin. Rept. No. LJ-79-29.

*SOPS/79/31 POWERS, J. E. and J. Barlow. 1979. Biases in the tuna-net sampling of dolphins in the eastern tropical Pacific.

SOPS/79/32 JENNINGS J. and R. K. Stives. 1979. Summary of preliminary results of a dolphin tagging feasibility study.

*SOPS/79/33 HENDERSON, J., W. F. Perrin, and Ruth B. Miller. 1979. Gross annual production in dolphin populations (Stenella spp) in the eastern tropical Pacific, 1973-1978.

SOPS/79/34 Not assigned.

SOPS/79/35 AU, D. W. K. 1979. Report of the porpoise survey cruises.

*SOPS/79/36 AU, D. W. K., W. L. Perryman, and W. F. Perrin. 1979. Dolphin distribution and the relationship to environmental features in the eastern tropical Pacific.

*SOPS/79/37 OHSUMI, S. 1979. Interspecies relationships among some biological parameters in cetaceans and estimation of the natural mortality coefficient of the southern hemisphere Minke whale. Rep. Int. Whal. Commn. 29, 1979.

SOPS/79/38 JACKSON, T. D. 1979. Trip report: porpoise population aerial survey of the eastern tropical Pacific Ocean, January 22-April 25, 1979.

SOPS/79/39 STAFF, PORPOISE/TUNA INTERACTION PROGRAM, Oceanic Fish. Res. Division, 1978. Aerial survey trip report, January-June 1977. SWFC Admin. Rep. LJ-78-01.

SOPS/79/40 PERRYMAN, W. L. 1977. Cruise Report: NOAA ship Townsend Cromwell, January 6-March 25, 1977.

SOPS/79/41 AU, D. W. K. 1977. Cruise Report: NOAA ship David Starr Jordan, January 4-March 8, 1977.

SOPS/79/42 PERRIN, W. F. AND T. KASUYA. 1977. Materials relevant to estimating natural mortality rate of the spotted dolphin in the eastern tropical Pacific (correspondence).

*SOPS/79/43 HENDERSON, J. R. AND W. F. PERRIN. 1979. Estimates of gross annual production of the common dolphin, Delphinus delphis, and the striped dolphin, Stenella coeruleoalba, in the eastern tropical Pacific, 1973-1978.

*SOPS/79/44 LO, N. C. H. and B. E. Wahlen. 1979. Summary tables and figures for kill statistics.

SOPS/79/45 HSU, S. B., S. P. HUBBEL, AND P. WALTMAN. 1978. A contribution to the theory of competing predators. Ecology Monographs 48: 337-349.

*SOPS/79/46 STAFF, PORPOISE/TUNA INTERACTION PROGRAM, Oceanic Fish. Res. Division. 1979. Number of data records collected by NMFS observers aboard U.S. tuna purse seiners, 1974-1979.

*SOPS/79/47 The Marine Mammal Protection Act of 1972. Public Law 92-522, 92nd Congress, H. R. 10420, October 21, 1972.

*SOPS/79/48 IATTC. 1979. Annual report of the Inter-American Tropical Tuna Commission.

SOPS/79/49 PERRIN, W. F., R. R. Warner, C. H. Fiscus, and D. B. Holts. 1973. Stomach contents of porpoise, Stenella spp., and yellowfin tuna, Thunnus albacares, in mixed species aggregations. Fish. Bull., U.S. 71(4): 1077-1092.

SOPS/79/50 LAAKE, J. 1979. Simulation of sampling distributions of abundance estimates.

*SOPS/79/51 GOODMAN, D. 1979. Interpretation of age distributions.

* Denotes key document